



**Lao National Agro-Ecology Programme PRONAE
PCADR**

Development and Implementation of Direct Seeding Mulch- Based Cropping Systems in South-East Asia

“Case studies from the Lao National Agro-Ecology

Edited by F. Tivet, H. Tran Quoc, P. Lienhard, A. Chabanne and K. Panyasiri
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Foreword

Farming is changing throughout Laos, with traditional slash-and-burn giving way to more modern agricultural methods in many areas. In southern Xayabury for example, traditional rotational cultivation has been replaced by cash crops such as maize, rice-beans, peanuts, Job's tears and sesame. Such development, when not carefully managed, can quickly deplete soils and nutrients. Maize is now widely sown and spreads to new areas every year: more than 15,000 ha was sown in southern Xayabury in 2004. Land preparation based on burning residues and ploughing on steep slopes has allowed for cultivation of large upland areas. However, within a few years this generates heavy soil degradation and depletion of natural resources, especially when crop rotation is abandoned. In many degraded areas of southern Xayabury, smallholders have modified conventional land preparation and are shifting from ploughing to herbicides.

In more remote areas, such as Xieng Khouang, the traditional swidden system is also changing. Intensified shifting cultivation, with longer periods of cropping and more frequent returns to a given field, has rendered this system unable to face the main challenges of food safety, soil and water conservation and environmental protection. Farming systems in this province show considerable diversity, with three main variations: around Phonesavanh, the provincial capital, infertile savannah grasslands are under-utilised by smallholders. On the higher plains farming systems are mainly based on lowland rice and extensive livestock production. In other more remote areas, particularly at the highest altitudes, upland rice production is the cornerstone, but population growth and shorter fallow periods are leading to lower yields. New opportunities are leading to different household production strategies in some areas, with increasing local and regional demand and better roads meaning that farmers now have markets for commercial crops.

Care must be taken to safeguard the environment as rural growth follows market demand. Even very good soils can be rapidly degraded, and damage to farmland has immediate negative social and economic impacts. Maintaining the productive capacity of soil is a crucial element for the long-term improvement of rural villages and poverty alleviation.

This publication gives an overview of the holistic research approach implemented by NAFRI and CIRAD, and of the process of generating soil conservation technologies with smallholders. This community-based approach to conservation agriculture involves smallholders and stakeholders throughout the research-development process and is an important step forward in safeguarding the future of Lao agricultural livelihoods.



About the Lao National Agro-Ecology Programme

The Lao National Agro-Ecology Programme (PRONAE) is a partnership between the National Agriculture and Forestry Research Institute (NAFRI) of the Lao Ministry of Agriculture and Forestry, and “le Centre de Coopération Internationale en Recherche Agronomique pour le Développement” (CIRAD). It is funded by the French Government through the French Agency for Development (AFD), the French Global Environment Facility (FFEM) and the French Ministry of Foreign Affairs.

PRONAE is working with smallhold farmers to develop soil conservation technologies. Project staff and smallholders generate, optimise and validate methods such as direct-seeding mulch-based cropping (DMC) systems. PRONAE started in 2002 in southern Xayabury and activities were extended to Xieng Khouang in early 2003. The approach, based on knowledge of local farming systems and environmental conditions such as morpho-pedological formations, access to market, credit and inputs, is composed of five components:

- ⊙ Initial assessment: agro-economic and social diagnosis of farming systems, human and physical environments provides a basis for generating technologies adapted to smallholders’ strategies and environmental conditions.
- ⊙ Setting up medium-term experimental units where conventional systems are continuously compared with DMC systems based on available technologies, and innovative DMC systems based on new technologies and inputs.
- ⊙ Adaptation and validation by smallholders of DMC systems and simple technologies:
 - On-farm implementation with farmer groups: agro-economic evaluation for labour requirement, production costs, yields, net income and labour productivity;
 - A community-based approach which focuses on the adoption of technologies at village level, taking into account collective land management.
- ⊙ Permanent training for smallholders, extension agents and information provision to policy makers.
- ⊙ Follow-up and analysis of the conditions of extension and adoption by farmers.

PRONAE Coordinators

Khamkéo PANYASIRI
Ministry of Agriculture and Forestry
National Agriculture and Forestry Research Institute

P.O. Box 811
Vientiane
Tel/Fax: (856) 21 77 00 27
E-mail : k_panyasiri@yahoo.com

Florent TIVET
Ministère de la Recherche
Centre de Coopération Internationale en Recherche
Agronomique pour le Développement
P.O. Box 2991
Vientiane
Tel/Fax: (856) 21 77 00 27
E-mail: tivet.florent@cirad.fr

NAFRI headquarter: Dong Dok, P.O. Box 7170, Vientiane, Lao PDR; Tel: (856 21) 770078; Fax: (856 21) 770047;
E-mail: contact@nafri.org.la; website: www.nafri.org.la

CIRAD Headquarters: Annual Crops Department, Research Unit “Agroecology, DMC systems”, TA 74/08, Avenue Agropolis, 34398 Montpellier, cedex 5; Tel: (33 4) 67615643; Fax: (33 4) 467617160, France;
E-mail: francis.forest@cirad.fr; website: <http://agroecologie.cirad.fr>

PRONAE Headquarters: Dong Dok, P.O. Box 10990, Vientiane, Lao PDR; Tel/Fax: (856 21) 770027

Front page photograph by Pierre Grard Landscape unit in southern Xayabury, Lao PDR.

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Introduction



Laos is a landlocked country (Map 1) with a total area of 236,800 km² and an average of 25 inhabitants per km². The agriculture and forestry sector accounts for more than 50% of GDP and provides the economic, social and cultural base for more than 80% of the population (GoL 2004). Rice is the most important crop, accounting for about 70% of total calorie intake across the nation (Maclean et al. 2002). In 2003, rice area harvested was approximately 756,000 ha, or 73% of the total cropped land area (MAF 2003). It is estimated that 620,000 households depend on agriculture and that 79% of these rely on subsistence farming. Farming systems throughout Laos have changed drastically over the last 15 years due to a range of factors. In some areas where market forces are prevalent (e.g. southern Xayabury in the Mekong corridor), shifting cultivation systems have given way to more conventional high-input agricultural systems. In other, more remote areas (e.g. Xieng Khouang province), the traditional swidden system with long rotations has been put under pressure, primarily due to modification of land access and increasing population. Intensification of shifting cultivation, with longer periods of cropping and more frequent returns to a given field, has rendered this system unable to face the main challenges of food safety, soil and water conservation and environmental

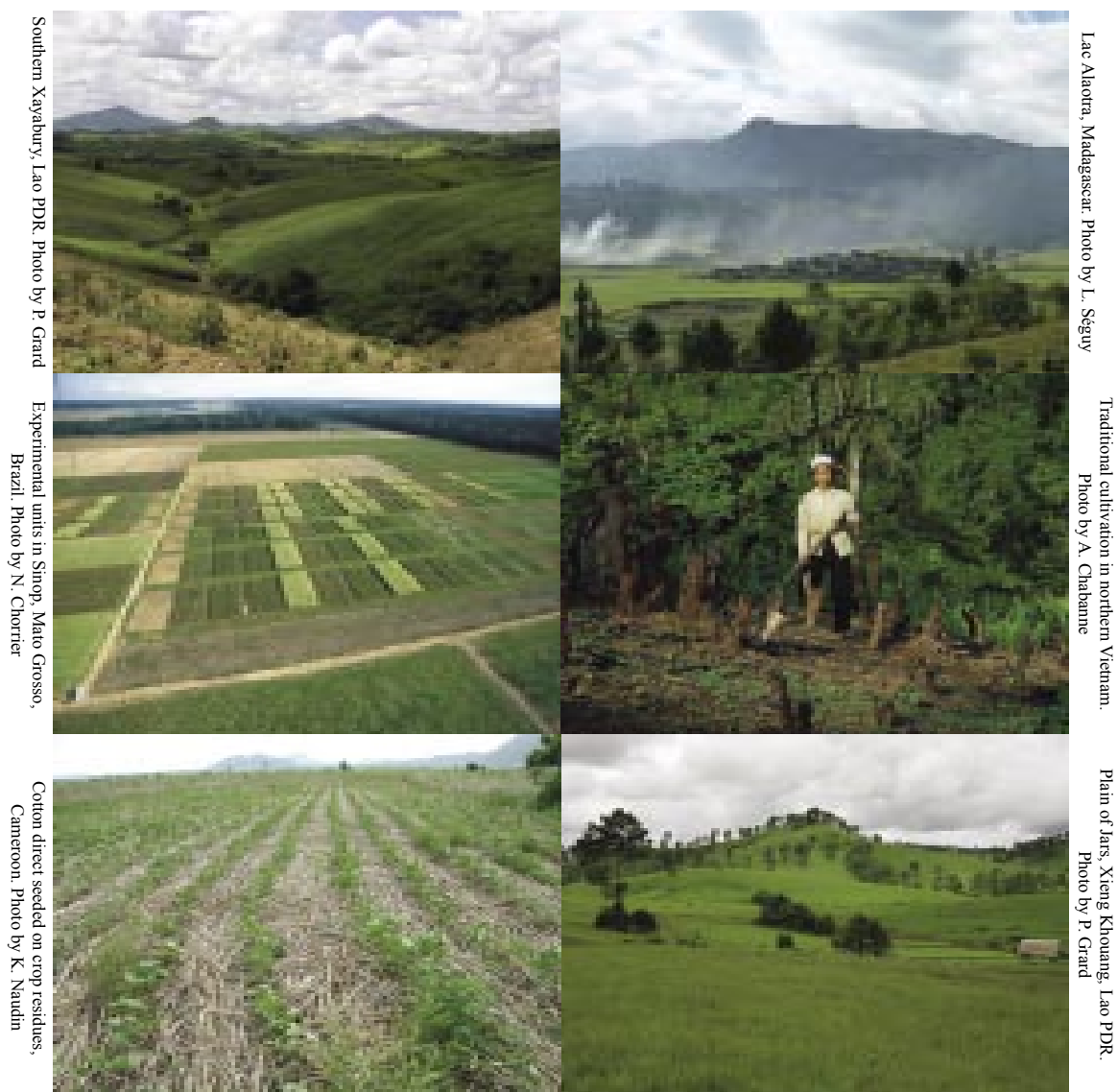
protection (Hansen and Sodarak 1996; Roder et al. 1997). Maintaining productive capacity of the soil is a crucial element for long-term improvement of smallholders' conditions and poverty alleviation (GoL 2004). During the past few decades, many approaches and alternatives based on bench terracing, reforestation and alley-cropping have been tested and scaled-up for the uplands without achieving the expected results (Fujisaka 1991; Roder 1997).

The objective of these proceedings is to give an overview of the holistic research approach implemented by NAFRI and CIRAD to find soil conservation technologies that are compatible with farmers' strategies and which can be reproduced inexpensively on a large scale.

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A Systemic Approach Based on Direct-sowing Mulch-based Cropping Systems to Promote Sustainable Agriculture in Southern Countries



Authors: Lucien Séguy and André Chabanne

Une approche systémique, reposant sur les systèmes de culture en semis direct sur couverture végétale, pour la promotion d'une agriculture durable dans les pays du Sud

A Systemic Approach Based on Direct-Sowing, Mulch-Based Cropping Systems to Promote Sustainable Agriculture in Southern Countries

Lucien Séguy¹ et André Chabanne²

1. CIRAD-CA, Goiânia, Goiás, Brazil, E-mail: lucien.seguy@cirad.fr
2. CIRAD-CA, PO Box 2991, Vientiane, Lao PDR, E-mail: andre.chabanne@cirad.fr

Résumé

L'approche agrosystémique développée pour les agricultures du nord n'a pu se réaliser qu'à un fort coût énergétique, social, environnemental et sanitaire, à la fois pour les agriculteurs et les sociétés. La durabilité de ces systèmes y est aujourd'hui fortement remise en cause. Les pays du Sud ne peuvent supporter ces coûts et risques. Les agrosystèmes y entraînent une plus forte et rapide dégradation des sols accentuée par des milieux biophysiques fragiles où les excès (notamment climatiques) sont plus sévères et fréquents. Les conditions sociales et économiques ne permettent pas, d'une part, une injection d'énergie auxiliaire suffisante pour maintenir la production de biomasse à des niveaux rentables et, d'autre part, la rémunération du capital sol, dont la valeur est donc consommée, sans contrepartie, par la production. Et, c'est pourtant dans le Sud que les capacités d'augmentation des surfaces agricoles et de productivité sont de loin les plus importantes.

L'Unité de Recherche travaille à la mise au point, à la proposition et à la diffusion d'alternatives reposant sur les techniques de semis direct avec couverture végétale (SCV). Elles tendent à reproduire le fonctionnement d'écosystèmes naturels complexes (notamment la forêt), en prenant en compte la nécessité d'une biodiversité dont les fonctions de régulation des cycles bio-géo-chimiques et de gestion des ressources naturelles sont essentielles. Il s'agit donc de remplacer les « agrosystèmes » par des « écosystèmes cultivés » permettant la promotion d'une agriculture durable.

L'analyse systémique développée cherche à pénétrer des « lois complexes » avec la plus grande généralité possible quant à la nature des systèmes. Les conditions d'existence et de pérennité des systèmes doivent alors apparaître sous forme de règles de gestion d'information interne qui les structure, les fait fonctionner et s'adapter, et également sous forme de règles de gestion de la matière, de l'énergie et de l'espace, depuis l'échelle locale jusqu'au terroir. Ces règles reposent sur l'existence de propriétés systémiques fondamentales.

Abstract

The agro-systemic approach developed for agriculture in the north has only been possible at a high energy, social, environmental and health cost for both farmers and societies. The sustainability of these systems is strongly doubted today. Countries in the south cannot support these costs and risks. There, agrosystems cause stronger, rapid soil degradation accentuated by fragile biophysical environments where excesses (especially climatic ones) are more severe and more frequent. Social and economic conditions allow neither the use of sufficient auxiliary energy to maintain biomass production at profitable levels, nor remuneration from soil capital whose value is thus used up. However, the capacity for increasing farmed areas and productivity is far larger in the south. The Research Unit is working on the development and dissemination of alternatives based on direct-sowing, mulch-based and conservation agriculture (DMC). This approach attempts to reproduce the functioning of complex natural ecosystems (especially forest) by taking into account the need for biodiversity with essential functions in the regulation of bio-geo-chemical cycles and the management of natural resources. This means replacing 'agrosystems' with 'cultivated ecosystems' that enable the promotion of sustainable agriculture. The systemic analysis developed seeks to understand 'complex laws' with as wide a coverage as possible of the nature of the systems. The conditions for the existence and sustainability of these systems must then be adopted as rules for the management of the information required to operate and adapt local

matter, energy and space at the soil scale. These rules are based on the existence of fundamental systemic properties.

Media summary

Les SCV, reproduisant le fonctionnement de l'écosystème forestier, permettent la restauration des fonctions naturelles de régulation nécessaires pour la promotion d'une agriculture durable.

Mots-clefs

Systèmes de cultures, semis direct, couvertures végétales, agriculture durable, agriculture de conservation, approche systémique, agrosystèmes, écosystèmes cultivés.

Contexte

Les systèmes de culture conventionnels ne peuvent supporter une agriculture durable dans les pays du Sud. Associés à des conditions socio-économiques fortement contraignantes et à des milieux biophysiques fragiles et déjà fortement dégradés, ils ne peuvent répondre ni aux besoins alimentaires et aux besoins de revenus d'une population en forte croissance démographique ni aux exigences de compétitivité de la mondialisation. Des techniques de conservation (aménagements anti-érosifs, techniques culturales simplifiées, agroforesterie...) sont déjà localement proposées mais elles sont souvent mal adaptées à la dynamique des réalités agricoles ou trop coûteuses, peu reproductibles ou insuffisamment efficaces. Dans ce contexte, comment offrir des alternatives techniques facilement appropriables par les acteurs du développement agricole et qui répondent à l'ensemble des critères de durabilité ?

L'interdépendance entre agriculture et environnement est aujourd'hui évidente. La mise en culture en milieu tropical provoque toujours de modifications très rapides et profondes des écosystèmes naturels (déforestation, brûlis annuel des savanes laissant les sols à nu) et entraîne des dégradations désastreuses de la ressource sol en particulier (érosion, lessivage des éléments nutritifs du profil cultural, perte rapide de la matière organique par minéralisation accélérée) et des ressources naturelles en général (externalités, contamination des eaux, perte de biodiversité). La terre va mal sous les tropiques, et d'autant plus mal que les modes de gestion mécanisée des sols transférés du Nord sont utilisés dans des milieux physiques, où les excès climatiques sont plus sévères et fréquents, et s'exercent sur des sols extrêmement fragiles, très vite déstabilisés dès que la couverture végétale disparaît sous l'emprise d'une démographie croissante de sociétés rurales déshéritées qui ne disposent, pour toute ressource, le plus souvent, que de celles du milieu naturel. La liaison entre la protection de l'environnement et la lutte contre la pauvreté doit s'inscrire dans les priorités d'intervention. On peut en effet douter de l'efficacité à long terme de projets d'amélioration des conditions de vie en milieu rural, si dans le même temps un effort significatif n'est pas fait pour garantir une préservation durable du capital environnemental. La sauvegarde, sur une base concertée et pérenne du potentiel de production est donc un élément essentiel d'amélioration de la sécurité à long terme des populations rurales défavorisées, et, à ce titre, s'intègre dans la lutte contre la pauvreté.

Enfin, et compte tenu des conditions socio-économiques contraignantes et des contraintes de compétitivité des marchés internationaux, une voie possible de lutte contre la pauvreté réside bien dans la qualité (sanitaire et organoleptiques) de la production pour satisfaire à la fois des marchés locaux de plus en plus exigeants et des filières d'exportation devant répondre aux normes internationales.

Etat des connaissances concernant ces enjeux et les grandes questions de recherche qui les sous-tendent

La population humaine à nourrir atteindra 7,5 milliards d'habitants en 2020, avec une augmentation démographique particulièrement élevée dans les pays du Sud. Dans les régions pauvres surpeuplées l'agriculture exercera une pression de plus en plus forte sur les terres et les forêts, sachant que ces dernières possèdent actuellement 70% de la biodiversité mondiale, constituent le « poumon » de la planète et séquestrent beaucoup de carbone, s'opposant à l'effet de serre. Ces ressources vont s'éroder, se dégrader ou disparaître, processus qui seront amplifiés par les déséquilibres provoqués par le changement climatique. Les productivités du travail et de la terre ne cesseront de diminuer.

La mise en valeur agricole des terres s'est principalement déroulée selon un processus de simplification d'écosystèmes naturels complexes. Elle s'est réalisée artificiellement :

- a) Par des défrichements (abattis-brûlis des forêts, feu des savanes), puisque la suppression de la biomasse est une des causes possibles de la simplification ;
- b) Par des pratiques tendant à diminuer la diversité (élimination d'espèces végétales et animales non utilisées, dites nuisibles ou parasites) ;
- c) Par des pratiques intensifiant la production nette (apports d'éléments nutritifs, amélioration des sols par amendements et labours, aménagement, irrigation...) ;
- d) Par la sélection de génotypes orientés vers une plus forte production nette et porteurs de résistances de plus en plus nombreuses induites par des milieux physiques de plus en plus dégradés, déséquilibrés.

La simplification observée s'est réalisée au détriment des fonctions naturelles de régulation des cycles bio-géo-chimiques intimement liées à la biodiversité et à la complexité systémique. L'agriculteur est alors obligé d'intervenir constamment et de façon diversifiée, par l'injection d'énergies auxiliaires, de matières (engrais, pesticides, variétés,...) et d'informations (structures imposées) pour maintenir les propriétés du système exploité. On parle alors « d'agrosystème », intimement lié à l'action humaine et ne présentant aucune stabilité et résilience.

Si cette approche a pu présenter temporairement un semblant de solution pour les agricultures du nord, elle n'a pu se réaliser qu'à un fort coût énergétique, environnemental et sanitaire, à la fois pour les agriculteurs et aussi pour l'ensemble des sociétés. Bien souvent, l'agriculture ne se maintient que par l'intermédiaire de subventions à la fois coûteuses et injustes, et par des phénomènes de concentration des moyens de production. Ces deux tendances soulèvent alors des problèmes d'équité. De plus, l'agriculture fait de plus en plus appel à des pratiques dont l'éthique reste à démontrer (OGM). La durabilité de tels systèmes y est aujourd'hui fortement remise en cause.

Mais les pays du Sud ne peuvent se permettre ces coûts et risques. Les systèmes de culture conventionnels avec travail du sol, directement transférés du Nord au Sud entraînent une plus forte et rapide dégradation des sols, dégradation accentuée par la fragilité de milieux biophysiques où les excès (notamment climatiques) sont plus sévères et fréquents. De plus, les conditions économiques (prix des intrants et des produits) ne permettent pas une injection d'énergies auxiliaires, de matières et d'informations suffisantes pour maintenir, d'une part, la production à des niveaux rentables, et, d'autre part, la rémunération du capital sol, dont la valeur est alors consommée sans contrepartie par la production.

Or, c'est dans le Sud que les potentialités d'augmentation des surfaces agricoles et de la productivité sont de loin les plus importantes. Malgré cela, on y observe une surexploitation d'écosystèmes naturels (forêts et savanes) dont la déstructuration compromet leur devenir ainsi que celui des sociétés. Et, parallèlement, on assiste à une très faible utilisation de vastes espaces fortement dégradés dont la mise en valeur n'est pas envisageable dans le contexte socio-économique local et selon des techniques conventionnelles.

Les enjeux de développement ainsi que les enjeux environnementaux et sanitaires qui en découlent sont majeurs pour les pays du sud situés dans un contexte de mondialisation et de compétitivité agricole contraignant (population rurale en situation précaire et en forte progression démographique, absence de subventions à l'agriculture, cours mondiaux défavorables, respects des conventions internationales, nécessité de répondre aux grands défis environnementaux et sanitaires...).

De plus, de part l'ensemble des sujets de recherche que ce constat sous-tend, les enjeux scientifiques sont considérables. Il s'agit de promouvoir une nouvelle approche systémique qui, partant de ces grandes problématiques de développement et environnementales, permettra d'orienter les grandes thématiques scientifiques appliquées directement au développement rural sur la restauration de fonctions naturelles de régulation pouvant assurer la stabilité et la résilience des systèmes de culture et d'exploitation.

Concepts novateurs de la gestion durable de la ressource sol : le semis direct sur couverture végétale permanente

Pour construire une agriculture durable en zone tropicale humide, sous climat particulièrement agressif où les sols, vides chimiquement, sont très sensibles à l'érosion et où les conditions de minéralisation de la matière organique sont exceptionnellement élevées, le CIRAD a dû faire appel à de nouveaux concepts de gestion de la matière organique (M.O.), inspirés directement du fonctionnement stable de l'écosystème forestier ; dans leur mise en oeuvre et leur perfectionnement continu depuis bientôt 20 ans, les sols, comme sous la forêt,

doivent être totalement maintenus couverts, protégés par une phytomasse végétale de plus en plus performante, et ne sont jamais travaillés (Séguy et al. 1996 ; 1998 ; 2001a ; 2001b ; 2001c).

La gestion de la matière organique (M.O.), renouvelable chaque année et au moindre coût, est au coeur de la construction agro-économique des systèmes de culture durables en semis direct, dans lesquels les outils biologiques ont remplacé les outils mécaniques. En zone tropicale humide (ZTH), où les conditions de minéralisation de la M.O. sont plus élevées que partout ailleurs sur la planète, l'introduction et la maîtrise de biomasses "de renfort" ou "pompes biologiques" comme intercultures dans les rotations et successions annuelles, se sont avérées incontournables pour bâtir une agriculture durable performante et diversifiée en semis direct continu sur couverture permanente du sol.

À l'image de l'écosystème forestier, ces biomasses de renfort multifonctionnelles (critères agronomiques et technico-économiques) garantissent la capacité et la stabilité de production du système "sol-plantes".

L'agriculture de conservation, et en particulier la gestion du capital sol en semis direct sur couvertures végétales permanentes, développée au Brésil et sur le réseau tropical SCV du CIRAD, offre les éléments d'une véritable révolution vers une agriculture durable en milieu tropical.

Pour répondre rapidement et durablement à cet échec, le CIRAD et ses partenaires de la recherche et du développement ont construit, maîtrisé et diffusé progressivement des systèmes de culture en semis direct sur couverture végétale permanente du sol. Ces systèmes, qui fonctionnent à l'image de l'écosystème forestier dont ils sont inspirés, ont été perfectionnés au cours du temps aux plans écologique, agronomique et technico-économique. Ils offrent, aujourd'hui, toutes les garanties de l'agriculture durable : de plus en plus productifs (plus de 28-30 t/ha de phytomasse sèche annuelle), avec de moins en moins d'intrants chimiques. Ils sont tous construits sur une reconquête de la biodiversité avec des sols toujours protégés sous couvertures mortes et/ou vivantes, biologiquement très actifs, qui séquestrent efficacement le carbone, favorisent la rétention des nutriments (CEC plus élevée) et fonctionnent en circuit fermé comme la forêt (recyclage profond des bases et nitrates, injection de carbone en profondeur).

Il a fallu adapter les caractéristiques essentielles de l'écosystème forestier aux systèmes de production agricole, car elles relèvent d'un fonctionnement systémique complexe mais remarquablement efficace et stable, capable d'assurer une productivité primaire élevée, et le recyclage du faible stock d'éléments minéraux présents, sans perte ni exportation.

Quelles caractéristiques du fonctionnement de l'écosystème forestier faut-il adapter aux systèmes de culture?

Il s'agit principalement de :

- * Laisser le sol toujours protégé sous une couverture végétale permanente (milieu tamponné, biologiquement très actif);
- * La possibilité d'une productivité primaire très importante de phytomasse, même sur sol très pauvre chimiquement et très acide;
- * La capacité à retenir la majeure partie du stock des éléments nutritifs non pas dans le sol mais dans la phytomasse (minimiser les pertes en nutriments, fermer le cycle du système Sol-Plante);
- * Créer un horizon de surface 0-5 cm, protégé, siège d'une activité biologique intense, qui, comme sous la forêt, assure l'essentiel du prélèvement des éléments nutritifs par les racines des cultures, les mycorhizes et la biomasse microbienne (Stark and Jordan 1978); et faire en sorte que ce recyclage biologique affecte comme sous la forêt, non seulement les éléments nutritifs tels que Ca, Mg et K dont le sol est quasiment dépourvu, mais aussi les minéraux tels que Si et Al qui jouent un rôle déterminant dans l'évolution de la composition minérale du sol (Lucas et al. 1993) et dans la résistance des cultures aux maladies.

ÉCOSYSTÈME FORESTIER AMAZONIEN ET MEILLEURS SYSTÈMES DE SEMIS DIRECT • Sds ferralitiques du sud du bassin amazonien - SincpMI, 1999		
	FORÊT	MEILLEURS SYSTÈMES DE SEMIS DIRECT
M. O. (0 - 20 cm)	18 t/ha C → litières + racines ⁶ 55 t/ha humus dont 44t/ha fortement liée matière minérale	14 - 20 t/ha litières + racines ¹⁰ > 40 à 50 t/ha humus
Porosité	Macropores dominants ⁷ (0,1 - 100 µm) ressuyage rapide MWD entre 4 et 5	Idem restructuration profil > 2 m ¹⁰ par racines graminées MWD entre 4 et 5
Utilisation eau par les plantes	Utilisation eau profonde ⁸ en saison sèche > 1,7 m	Utilisation eau profonde ¹⁰ fin saison pluies et saison sèche > 2m - Coton, Sorgho, Mil, Tournesol, pâturage temporaire
Cycle des éléments nutritifs	Majeure partie prélèvement ⁹ nutriments → entre 0 et 5 cm de profondeur	Reconstitution horizon 0 - 5 cm ¹⁰ Nourricier - systèmes racinaires en chandelier Important recyclage profond
← Nutrition entre M. O. Vivante et morte → Peu d'échanges avec sol minéral		
SOURCE: 6. Cerri et al., 1992; 7. Cabral, 1991; Leopoldo et al., 1987; 8. Pimentel da Silva et al., 1992; 9. Stark et Jordan, 1978; Lucas et al., 1993; Luizão et al., 1992; 10. Ségué L. et Bouzinac S., CIRAD/GEC - 1990-99.		

Figure 1 : Comparaison entre écosystème forestier brésilien et les meilleurs systèmes de semis direct avec couverture végétale

ÉCOSYSTÈME FORESTIER AMAZONIEN ET MEILLEURS SYSTÈMES DE SEMIS DIRECT • Sds ferralitiques du sud du bassin amazonien - SincpMI, 1999		
	FORÊT	MEILLEURS SYSTÈMES DE SEMIS DIRECT
Biomasse litière	8,4 t/ha ¹	10 - 15 t/ha ¹⁰ (Grains + <i>Brachiaria</i> R.)
Vitesse décomposition litière	50% poids en 37 jours, ² saison des pluies 50% poids en 216 jours, saison sèche	50% poids en 30 jours, ¹⁰ (Maïs, Riz)
Biomasse racinaire	± 5 t/ha ³ 60% 0 - 20cm 80% 0 - 40 cm	5 - 7 t/ha ¹⁰ (Grains + <i>Brachiaria</i> R.)
Biomasse microbienne	1,9 à 3,3% C ⁴ (0 - 5 cm)	À chiffrer
Biodiversité P. Aérienne	175 à 235 espèces ⁵ 43 à 49 familles + animaux	3 espèces ha/an ¹⁰ + bovins
SOURCE: 1. Luizão, 1989; 2. Luizão et Shubart, 1987; 3. Chauvel et al., 1987; 4. Lavelle et al., 1991; 5. Prance et al., 1976; Barbosa, 1988; 10. Ségué L. et Bouzinac S., CIRAD/GEC - 1990-99.		

Figure 2 : Comparaison entre écosystème forestier brésilien et les meilleurs systèmes de semis direct avec couverture végétale (suite)

Comment restaurer et maintenir les fonctions naturelles de régulation : la notion de pompe biologique

En réalité, dans la pratique, il s'agissait de recréer à partir d'un état de dégradation avancée, une dynamique de transformations fondamentales sur et dans le sol sous culture, qui le ramène progressivement à ses modes de fonctionnement originels sous forêt (résilience), tout en construisant une agriculture plus productive et rentable, diversifiée, durable et propre.

Diverses étapes ont été nécessaires pour réaliser cette reconversion opérationnelle. Elle a été bâtie progressivement par l'insertion dans les systèmes de culture, de biomasses de renfort, renouvelables, pratiquées en interculture (avant ou après les cultures ou en association avec elles), appelées "pompes biologiques" en raison de leur analogie de comportement avec la phytomasse forestière pour ce qui concerne leur multifonctionnalité.

Parmi les fonctions agronomiques essentielles requises qu'elles doivent exercer pour compléter l'action propre des cultures dans les systèmes, on peut citer:

Au-dessus du sol :

- * **Protection totale et permanente** de la surface contre les excès climatiques (Rôle d'écran régulateur pour l'eau et la température, et d'écran protecteur pour la faune et les molécules de pesticides, d'amortisseur pour le passage des engins et animaux lourds) ;

- * **Fonction alimentaire** pour la culture principale (réglée par C/N et teneur en lignine des parties aériennes et racinaires) et fonction alimentaire pour les animaux (intégration de l'élevage, vocation fourragère des biomasses), pour la faune, la microflore du sol (regain de biodiversité) ;

- * **Fonction de contrôle des adventices** par effets d'ombrage et/ou allélopathiques (contrôle de *Cyperus rotundus* par exemple grâce à une couverture de sorgho).

Au-dessous du sol

- * **Coudre le sol**, dès les premiers centimètres par les systèmes racinaires (supprimer la battance, fixer le sol);

- * **Restructuration du sol** par un puissant pouvoir d'agrégation du système racinaire (trame racinaire, trame de sustentation du sol), qui lui confère des propriétés physiques et biologiques très performantes. La restructuration effective du profil cultural se fait grâce à la production de substances très efficaces pour l'agrégation : les polysaccharides et les endomycorhizes vésiculo-arbusculaires (Doss et al. 1989). Les espèces *Eleusine coracana* et *Brachiarias ruziziensis*, *decumbens*, *humidicola* sont exemplaires à cet égard où les racines sont fortement engainées dans un manchon protecteur de micro agrégats;

- * **Recyclage des nutriments** lixiviés en profondeur (fermeture du système "sol - Culture"), en particulier les nitrates, K, Ca, Mg, qui sont remontés en surface grâce aux systèmes racinaires très puissants à la fois dans leur capacité de développement en profondeur, et dans leur fort pouvoir d'interception des nutriments et molécules organiques;

- * **Utilisation de l'eau profonde du sol**, en dessous de la zone de pompage des cultures commerciales à l'image de l'écosystème forestier en saison sèche. Cette capacité de se connecter à la réserve d'eau profonde permet de produire de la biomasse verte en saison sèche, d'injecter du carbone en continu dans le profil cultural et en profondeur, et d'entretenir une activité biologique soutenue ;

- * **Capacité à mobiliser de la fertilité** : extraction de nutriments par le système racinaire, même en sol très pauvre et acide, puis remise à la disposition des cultures par minéralisation de la matière sèche ; par exemple, les graminées des genres *Eleusine* et *Brachiaria* fixent de l'azote dans leurs rhizosphères grâce à des bactéries non symbiotiques et sont capables grâce à l'endomycorhisation vésiculo-arbusculaire de mobiliser des formes insolubles de phosphore; les légumineuses des genres *Cajanus*, *Crotalaria*, *Stylosanthes* fixent gratuitement l'azote de l'air par voie symbiotique ; ces graminées et légumineuses peuvent être utilisées en mélange pour constituer des pompes biologiques polyvalentes.

- * **Développement d'une forte activité biologique** soutenue toute l'année. Les puissants systèmes racinaires de sustentation du sol constituent des milieux privilégiés, car protégés et remaniés au minimum (semer spécifique pour le semis direct), et sont ainsi propices au développement et à l'activité de la faune et de la microflore.

- * **Pouvoir désintoxiquant** des biomasses végétales de couverture (biorémédiation) contre les molécules polluantes des pesticides (effet de la couverture de sorgho + *Crotalaria* sur la molécule Sulfentrazone) contre la toxicité aluminique (les genres *Cassia*, *Brachiaria* et *Stylosanthes*) ou contre la salinité (acides organiques divers libérés lors de la minéralisation des biomasses de couverture qui exercent un fort pouvoir neutralisant, complexant (Miyizawa M. et al 2000).

Au-delà de leur multifonctionnalité agronomique (Figure 3), les pompes biologiques doivent répondre à des critères technico-économiques qui facilitent leur adoption et leur reproduction au moindre coût et à grande échelle, par les agriculteurs : niveau de technicité requis et forte valeur ajoutée (production additionnelle en saison sèche de fourrages, pâture, grains pour les animaux, mais aussi compléments pour l'alimentation humaine).

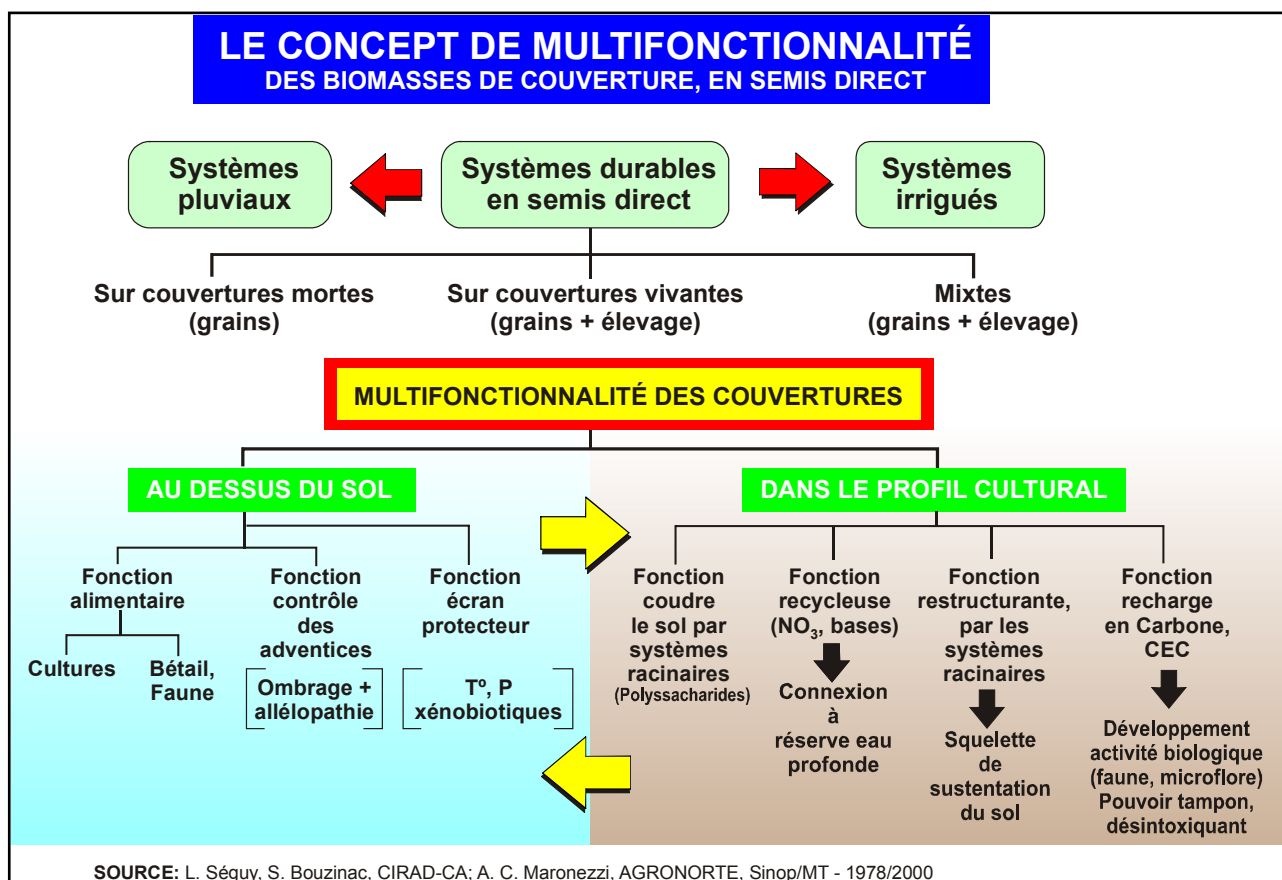


Figure 3: le concept de multifonctionnalité

Comment insérer les « pompes biologiques de renfort » dans les systèmes de culture ?

Elles peuvent être constituées au début des pluies. Elles seront alors desséchées (chimiquement ou mécaniquement) pour constituer le paillage des cultures commerciales. Et elles peuvent aussi être réalisées après les productions commerciales en fin de saison des pluies. Elles seront alors récoltées et doivent offrir une valeur ajoutée attractive pour les producteurs. Leur choix (Séguy et al 1996, 1998, 2001a ; 2001b ; 2001c) se fait en fonction de leur capacité à exploiter l'eau disponible en surface au début des pluies, et en profondeur en fin de saison des pluies, le plus souvent en conditions de pluviométrie très aléatoire.

Les « pompes biologiques » peuvent aussi être des espèces pérennes à stolons et rhizomes (par exemples, les genres *Arachis*, *Stylosanthes*, *Pueraria* chez les légumineuses, et les genres *Cynodon*, *Paspalum*, *Stenotaphrum*, *Pennisetum* chez les poacées), qui constituent des couvertures vivantes pérennes à vocation fourragère. Elles sont maintenues à l'état de vie ralentie, donc non-concurrentielles sous les cultures commerciales grâce à l'utilisation d'herbicides non polluants. Elles reprennent leur plein développement végétatif après la récolte de ces dernières et peuvent être pâturées en saison sèche.

Les « pompes biologiques » associées qui sont fonctionnelles en fin de cycle des pluies et en saison sèche ainsi que les couvertures vivantes pérennes, lorsque elles sont bien gérées dans les systèmes de culture, permettent de produire une très importante phytomasse et ceci toute l'année. C'est au cours de la saison sèche, plus fraîche, où la minéralisation de la matière organique est minimum, que la forte production de biomasse au-dessus du sol et dans le profil cultural en surface et en profondeur (grâce à l'utilisation de la

réserve d'eau profonde) permet d'accumuler un maximum de carbone et d'exercer un puissant recyclage des bases et nitrates lessivés.

Méthodologie de la recherche-action: •construire l'innovation pour, chez et avec les agriculteurs

La construction des SCV dans les pays du Sud et plus récemment en Europe (Transfert Sud-Nord) s'inscrit dans la démarche de Recherche-Action participative (Séguy et al. 1996 ; 2001a). Schématiquement, elle procède, avec les agriculteurs et autres acteurs du développement, en partant de leurs systèmes actuels et de leurs limitations, d'abord d'une modélisation pratique des systèmes de culture de demain, puis de leur maîtrise en vraie grandeur ; c'est de la qualité de cette modélisation (hiérarchisation des composantes au cours du temps) et de son niveau de maîtrise technique que dépend la rigueur des recherches thématiques explicatives de leur fonctionnement comparé. La recherche scientifique, qui doit d'abord être utile, est ainsi connectée avec les réalités agricoles d'aujourd'hui et avec la construction de leurs possibilités de demain, appropriables par les agriculteurs (agronomie préventive qui pratique le principe de précaution).

Cette recherche in situ, dite de "création-diffusion-formation" (Séguy et al. 1994 ; 1996 ; 2001a) s'appuie sur des unités expérimentales qui sont gérées par les chercheurs et les agriculteurs, et sur des fermes de référence dans lesquelles les producteurs volontaires, charismatiques et influents, appliquent les systèmes qu'ils ont choisis sur les unités expérimentales, en l'état ou en les réadaptant. L'ensemble des fermes de référence est représentatif de la variabilité régionale (milieux physique et socio-économique). Dans les fermes expérimentales, les systèmes de culture sont organisés en matrice sur des toposéquences (Figure 4) représentatives du milieu (types de sols, états de dégradation, etc.).

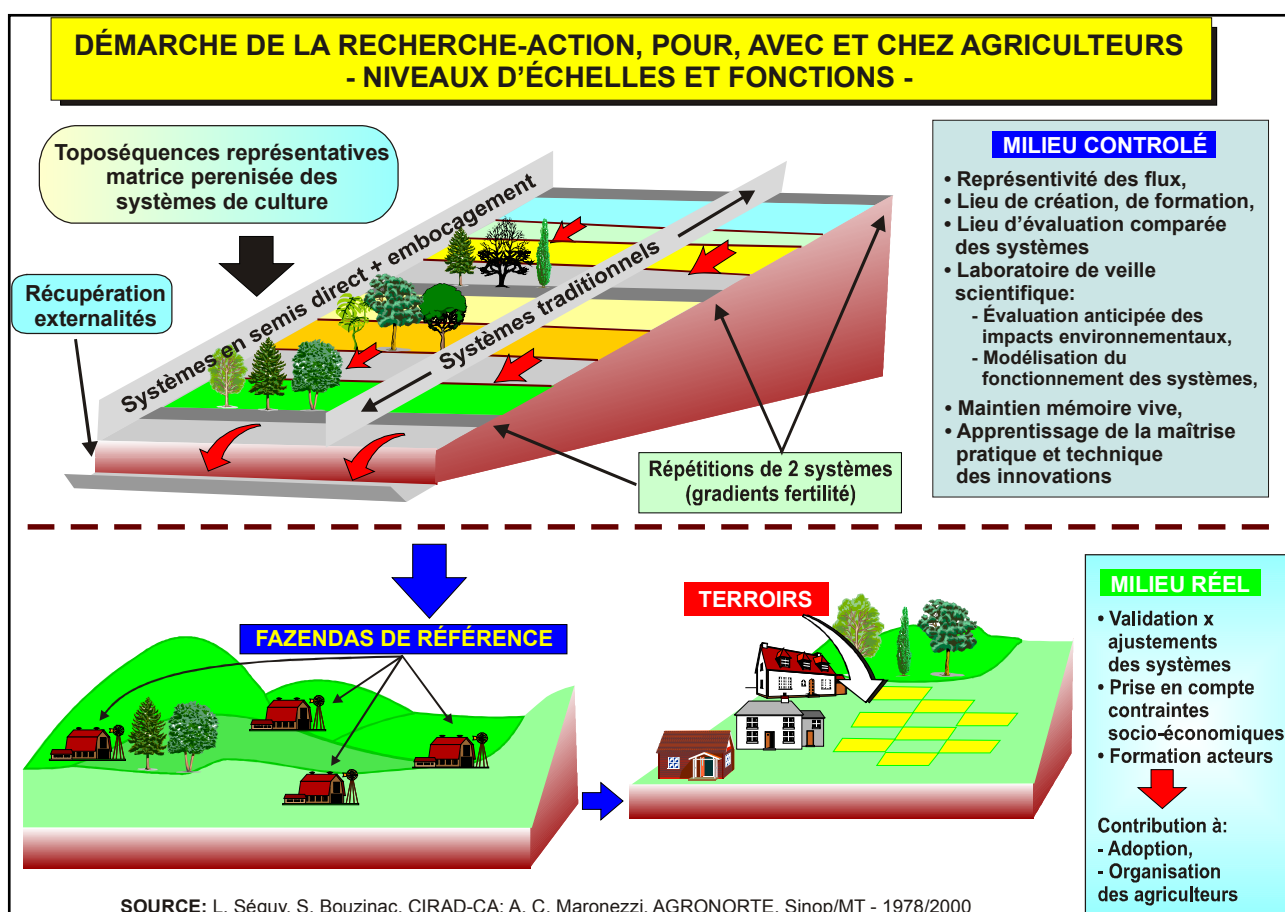


Figure 4: La méthodologie de Recherche-Action, niveaux d'échelles et fonctions.

Partant des systèmes traditionnels, les nouveaux systèmes sont élaborés par l'incorporation progressive, organisée et contrôlée de facteurs de production plus performants. La construction des matrices obéit à des règles précises, qui permettent l'interprétation des effets directs et cumulés des composantes des systèmes au cours du temps (Figure 5). Les matrices et les fermes de référence sont des lieux d'action, de création de l'innovation et de formation ; elles constituent un laboratoire de veille précieux pour les scientifiques, et un vivier de systèmes de culture diversifiés (SCV de production exclusive de grains, ou intégrant l'élevage, ou l'élevage et l'arbre dans le paysage cultivé).

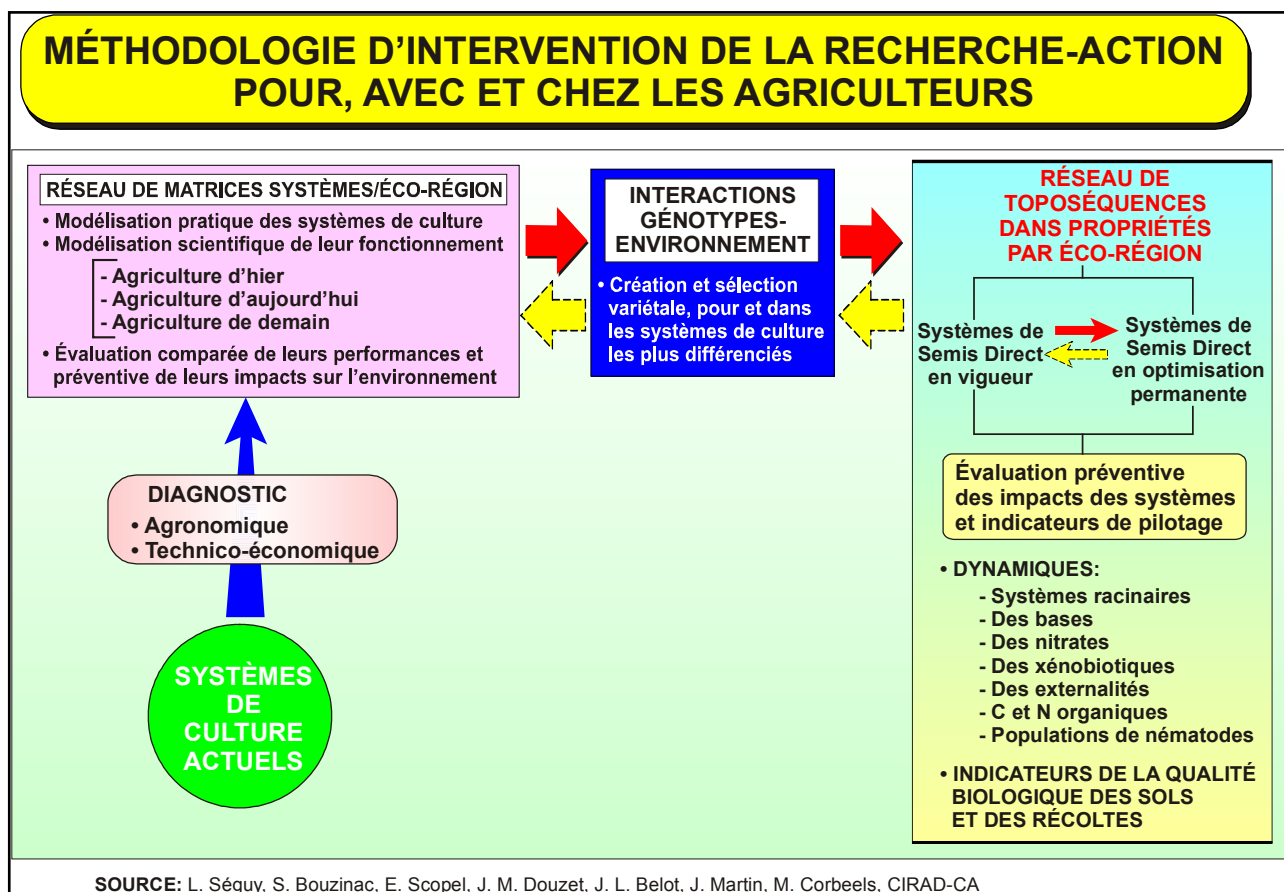


Figure 5: La méthodologie de Recherche-Action

Cet ensemble méthodologique répond aux grands objectifs de la recherche-action finalisée :

- * Adéquation avec les problématiques agricoles et la demande du sud
- * Création des innovations technologiques avec, pour, et chez les agricultures du sud, et diffusion à des niveaux d'échelle significatifs, convaincants pour tous les acteurs
- * Production de connaissances scientifiques,
- * Formation de tous les acteurs de la R-D.

Impacts sur les problèmes de développement

Lutte contre la pauvreté et les inégalités

- * Restauration et amélioration continue, avec le temps, du capital sol sous culture, des agriculteurs ;
- * Augmentation de la productivité du travail des agriculteurs et diminution de sa pénibilité ;
- * Augmentation de la diversification des systèmes de culture (regain de biodiversité utile), de leurs marges nettes et de leur stabilité économique ;
- * Libération de temps pour d'autres activités lucratives (artisanat, commerce, de gestion de ressources collectives) ou de loisir ;

* Amélioration de la compétitivité de l'agriculture du sud par la diminution des coûts de production (intrants...), la qualité des productions (produits exempts de résidus agrottoxiques, riz aromatiques, etc..) à forte plus-value car répondant à la demande prioritaire de la société civile mondiale ;

* Dans la perspective d'un futur «marché du carbone» vente de «droits à polluer» par les agricultures SCV qui augmentent ainsi la séquestration du carbone.

Objectifs des conventions internationales

* La désertification : régénération des sols, économie de l'eau, augmentation de la biomasse et de l'activité biologique des sols dans les savanes à sols dégradés en pourtour des régions arides ou semi-arides.

* La biodiversité : contribution à la protection des forêts inter-tropicales donc des espèces végétales et animales qui les composent, grâce à la fixation de l'agriculture et à la diminution du « slash-and-burn ». Protection des réserves naturelles par fixation de l'agriculture et suppression des jachères, apports vivriers et de revenus agricoles monétaires évitant la chasse des espèces protégées (Afrique Australe).

* L'effet de serre : bilan positif de séquestration de carbone par les SCV (1,5 à 3 t/ha/an de carbone sur 10 ans). Effet indirect : protection de la forêt (rôle de puits de carbone). Il faut faire accepter par les instances internationales, le rôle de sols comme puits possibles de carbone.

* L'eau : économie de l'eau dans les cultures « pluviales » en SCV mais aussi en aquatique et irrigué (riziculture) si protection des versants par les pratiques de couverture des sols. Contribution à la moindre pollution des nappes (azote, résidus toxiques) grâce aux SCV, particulièrement leurs plantes de couverture.

Politiques publiques

Les SCV, pour entrer dans les mœurs et les esprits, nécessitent autour des agriculteurs, une conscientisation et une sensibilisation de tout un système d'acteurs, privés et publics, en particulier les collectivités décentralisées et les services des ministères pour qu'ils assurent la promotion des SCV, la formation des acteurs dans leur politique, qu'ils instaurent des subventions éco-conditionnelles, qu'ils détaxent certains intrants en favorisant la création d'organisation paysannes etc...

La pratique des SCV peut s'inscrire dans le cadre de réglementations territoriales concernant la gestion de l'exploitation et de la protection des ressources communautaires (eaux, sols, pâturages, forêt, faune, infrastructures,...), aux niveaux d'échelle « terroirs », « bassin versant » ou zones protégées. Les parties aval à protéger ces territoires peuvent aussi être concernées.

Un réseau international et le plan d'action agroécologie CIRAD/ AFD/ FFEM/ MAE

Avec ses nombreux partenaires, le CIRAD développe un important réseau de recherche pour adapter ces techniques à un large éventail de situation bio-physiques et socio-économiques:

* des sols pauvres aux plus riches;

* des zones tempérées aux régions sub-tropicales, tropicales et équatoriales;

* des régions sèches (450 mm/an en Tunisie) aux régions tropicales humides (entre 2000 et 3000 mm de pluie en Amazonie);

* du niveau de la mer aux zones d'altitude (hautes terres malgaches);

* des plaines (y compris les rizières bien et mal irriguées les plus pauvres) aux zones de pentes fortes (Nord Vietnam);

* différents niveaux d'intensification, avec l'agriculture intensive, à forte capacité d'investissement en capital et en fournitures, jusqu'à l'agriculture extensive, sans intrants, pour les agriculteurs plus pauvres,

* différents niveaux d'intégrations aux marchés, depuis les régions intégrées au marché mondial (Brésil) jusqu'aux montagnes enclavées (Vietnam),

* un large éventail de densités de population.

L'Agence Française de Développement (AFD), le Fond Français pour l'Environnement Mondial (FFEM), et le Ministère des Affaires Etrangères (MAE) partagent leurs efforts pour appuyer un Plan d' Action en Agroécologie (PAA), finançant le programme de recherche et de développement dans cinq pays pilotes (Cameroun, Laos, Madagascar, Mali et Tunisie).

Un unité de recherche structurée pour une finalité immédiate de développement agricole

De part sa nature et son historique, l'Unité de Recherche CIRAD/SCV repose sur des projets nationaux opérationnels fortement orientés vers la recherche finalisée (développement). Cela suppose que :

- * les activités de recherche soient structurées prioritairement non pas à partir de grandes thématiques scientifiques importées du nord mais à partir de projets conduits en partenariat, construits en adéquation avec les problématiques agricoles et la demande du Sud, et pour lesquels des résultats rapides en terme de développement sont attendus de la part de l'ensemble des partenaires;

- * les activités de recherche doivent être priorisées en fonction de leur applicabilité immédiate pour la création, l'évaluation et la diffusion des SCV (appui à la formation, à la prise de décision et à l'organisation).

Afin de préserver cette approche, la structuration de l'unité de recherche ne repose pas sur le principe « des terrains au service d'un projet scientifique » mais, inversement, sur le principe « un projet scientifique au service d'une finalité immédiate et de l'agriculture durable à plus long terme ». Cette structuration est aussi la seule qui garantisse que l'approche systémique proposée repose bien sur le principe holistique, l'approche analytique permettant quant à elle d'expliquer les processus complexes mis en jeu et, aussi, d'alimenter la conception de l'offre technologique. Les systèmes définissent, au cours du processus de production, la nature, l'importance et la hiérarchisation des thèmes.

Cette approche nécessite aussi une organisation régionale construite autour de plateformes régionales en partenariat. De part son historique, l'ensemble des projets conduits sont déjà plus ou moins structurés à un niveau régional. On peut déjà distinguer les ensembles fonctionnels suivants :

- * l'Océan Indien et l'Afrique Australe à partir de Madagascar ;
- * l'Asie du Sud Est à partir des projets nationaux du Laos, Cambodge, Vietnam, Thaïlande et Chine ;
- * l'Afrique de l'Ouest et Centrale à partir du Cameroun et du Mali,
- * l'Afrique du Nord et le pourtour méditerranéen à partir de la Tunisie et du Maroc;
- * l'Amérique du Sud et Centrale à partir du Brésil.

Ces ensembles combinent la diversité bio-physique et socio-économique rencontrée en zones tropicales et sub-tropicales humides et semi-arides.

Conclusion

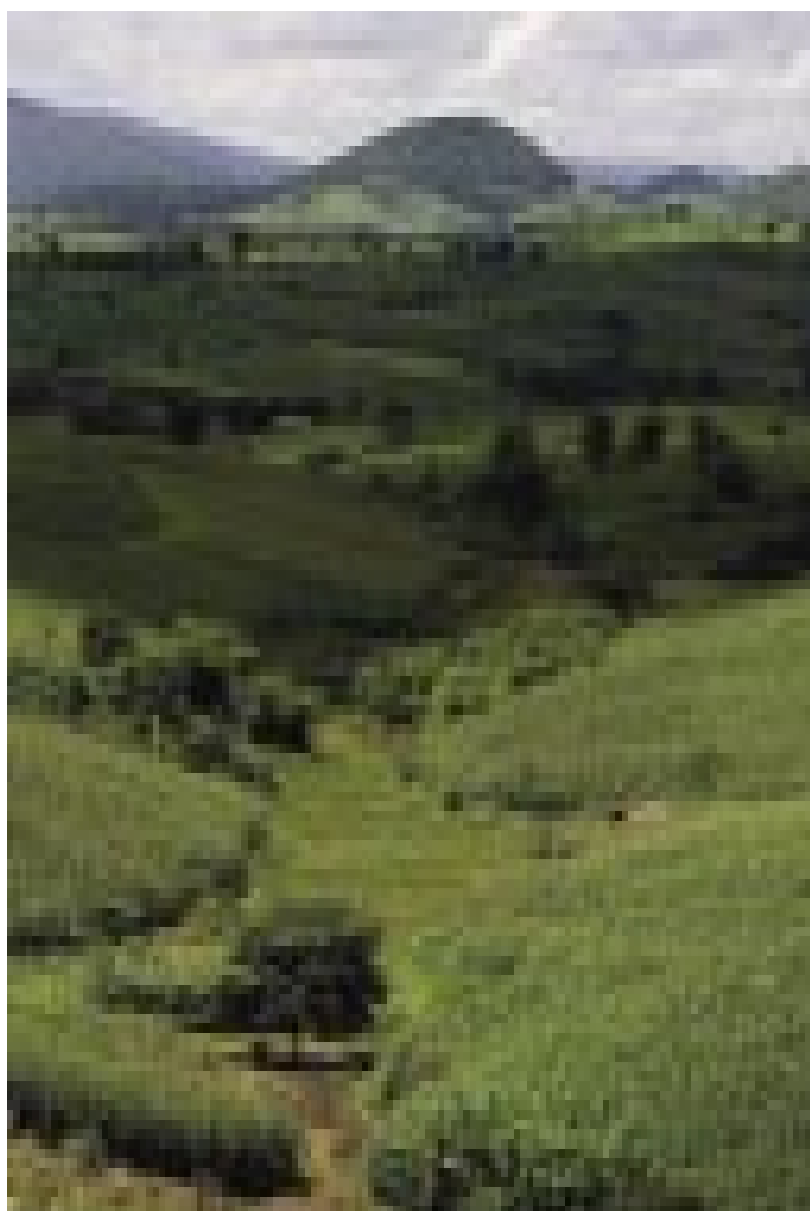
La gestion des écosystèmes cultivés en semis direct sur couverture permanente du sol a permis de convertir un cycle de dégradation accélérée des sols dû aux techniques de travail du sol transférées des pays du Nord, en un cycle de reconstruction de leur fertilité. Ce mode de gestion, qui fonctionne à l'image de l'écosystème forestier, est le seul qui restaure et maintienne les fonctions naturelles de régulation des cycles bio-géo-chimiques. Le sol est totalement protégé contre l'érosion et les xénobiotiques, même sous les climats les plus agressifs. Par le potentiel développé de recyclage, les éléments nutritifs comme les nitrates, les bases telles que le calcium, le magnésium, la potasse, ne sont pas entraînés vers la nappe phréatique, mais au contraire, remontés en surface et toujours recyclés. La production de phytomasse est continue durant toute l'année, grâce à l'utilisation des réserves d'eau en profondeur. Cette connexion se fait par l'intermédiaire de systèmes racinaires très puissants qui injectent du carbone en profondeur et est ainsi protégé des actions anthropiques.

Les scénarios d'agriculture durable, qui ont été créés grâce au semis direct sur couverture végétale permanente, sont tous construits sur une reconquête de la biodiversité. Les rotations des cultures, la meilleure intégration de l'agriculture et de l'élevage, des sols toujours protégés sous couvertures mortes ou vivantes qui favorisent le développement de la faune du sol et de l'activité biologique en général (macro, méso et microfaunes, microflore), sont autant de facteurs favorables à l'évolution des systèmes cultivés vers le fonctionnement des écosystèmes naturels (Résilience). Les efforts prioritaires doivent maintenant porter sur la formation et sur la diffusion des SCV les plus performants, intégrant l'agriculture, l'élevage, l'arbre, qui permettent d'offrir des productions de qualité à haute valeur ajoutée avec moins d'intrants chimiques, et qui soient capables de restaurer au moindre coût et au cours du processus de production, l'énorme potentiel des sols tropicaux déjà très fortement dégradé.

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Direct-Seeding Mulch-Based Cropping Systems – A Holistic Research Approach in Northern Laos



Kenthao district, Xayabury Province. Photo by P. Grand

Authors: Bounthong Bouahom, Florent Tivet, Hoà Tran Quoc, Pascal Lienhard, Bounsay Chantharath, Khamkèo Panyasiri, Patrick Julien and Lucien Séguéy

Direct-Seeding Mulch-Based Cropping Systems A Holistic Research Approach implemented in Northern Laos

Bounthong Bouahom¹, Florent Tivet², Hoà Tran Quoc², Pascal Lienhard², Bounsay Chantharath¹, Khamkèo Panyasiri¹, Patrick Julien³, and Lucien Séguy⁴

1. NAFRI, PO Box 7170, Vientiane, Lao PDR, E-mail: bounthong@nafri.org.la
2. CIRAD-CA, PO Box 2991, Vientiane, Lao PDR, E-mail: ciradca@laotel.com
3. Local consultant, PO Box 749, Luang Prabang, Lao PDR
4. CIRAD-CA, Goiânia, Goias, Brazil, E-mail: lucien.seguy@cirad.fr

Abstract

Farming systems throughout the Lao PDR have changed drastically over the last 15 years due to a range of factors. In some areas where market forces are prevalent, shifting cultivation systems have given way to more conventional high-input agricultural systems. In other more remote areas, the traditional swidden system with long rotations has been put under pressure primarily due to modification of land access and increasing population pressure. In southern Xayabury in the Mekong corridor, where there is access to the Thai market, land preparation has become based on burning residues and ploughing on steep slopes. Because of the environmental and financial costs of land preparation, farmers are shifting to herbicides, which lead to chemical pollution, while crop residues and weed mulch are usually burned, thereby increasing mineral losses and erosion on bare soil. In mountainous areas such as Xieng Khouang Province, the rationale of shifting cultivation is collapsing as farmers use land for longer periods of cropping and return more frequently to each field. A holistic research approach has been implemented in Xayabury and Xieng Khouang to find direct-seeding mulch-based cropping (DMC) systems that are compatible with farmers' strategies and which can be reproduced inexpensively on a large scale. The methodological framework, based on five main components, emphasises the process of adaptation and validation by farmer groups, meaning that priorities are defined by smallholders in light of the constraints of their farming systems and the overall environmental conditions.

Media summary

This paper gives an overview of the holistic research approach implemented by NAFRI and CIRAD in the Lao PDR in adapting soil conservation technologies with farmer groups.

Keywords

Laos, holistic research approach, direct-seeding mulch-based cropping systems, farmer groups, process of adoption.

Introduction

Laos is a landlocked country (Map 1) with a total area of 236,800 km² and an average of 25 inhabitants per km². The agriculture and forestry sector accounts for more than 50% of the GDP and provides the economic, social and cultural base for more than 80% of the population (GoL 2004). Rice is the most important crop, accounting for about 70% of total calorie intake across the nation (Maclean et al. 2002). In 2003, rice area harvested was approximately 756,000ha, or 73% of the total cropped land area (MAF 2003). It is estimated that 620,000 households depend on agriculture and that 79% of these rely on subsistence farming. Farming systems throughout Laos have changed drastically over the last 15 years due to a range of factors. In some areas where market forces are prevalent (e.g. southern Xayabury in the Mekong corridor), shifting cultivation systems have given way to more conventional high-input agricultural systems. In other, more remote areas (e.g. Xieng Khouang province), the traditional swidden system with long rotations has been put under pressure



primarily due to modification of land access and increasing population pressure. Intensification of shifting cultivation, with longer periods of cropping and more frequent returns to a given field, has rendered this system unable to face the main challenges of food safety, soil and water conservation and environmental protection (Hansen and Sodarak 1996; Roder et al. 1997). Maintaining productive capacity of the soil is a crucial element for long-term improvement of smallholders' conditions and poverty alleviation (GoL 2004). During the past few decades, many approaches and alternatives based on bench terracing, reforestation and alley-cropping have been tested and scaled-up for the uplands without achieving the expected results (Fujisaka 1991; Roder 1997). The objective of this paper is to give an overview of the holistic research approach implemented by NAFRI and CIRAD and of the iterative process of generating direct-seeding mulch-based cropping (DMC) systems with smallholders. This approach has been implemented by the Lao National Agro-Ecology Programme since 2002 in southern Xayabury and was extended to Xieng Khouang in early 2003.

Characteristics of Southern Xayabury and Xieng Khouang Provinces

Southern Xayabury Mekong Corridor

The main characteristics of this region are its integration with the Thai market and the transfer of technologies from Thailand. The climate is characterised by a wet season (approximately 1,250 mm rainfall) from mid-April to the end of October and a dry season from November to mid-April. Sandstone, basaltic 'green' stones and clayey schist are the dominant geological formations. Traditional rotational cultivation has changed drastically here since the 1990s, through extensive agricultural development based on cash crops such as maize, rice-beans, peanuts, Job's tears and sesame production). Cropping is largely opportunistic, related to the demands of the Thai market. Land preparation, based on burning residues and ploughing on steep slopes, has allowed for cultivation of large upland areas every year. Within a few years, this conventional land preparation generates heavy soil degradation and depletion of natural resources, and seasonal migration frequently occurs due to collapsing livelihoods.

Xieng Khouang Province

Farming systems in this province show considerable diversity, related to the presence of several ethnic groups, differences in access to market, and varying geological and morpho-pedological formations (granite, sandstone, limestone). Three main situations can be presented. In the vicinity of the provincial capital, it is estimated that more than 60,000ha of acid, infertile savannah grasslands are under-utilised by smallholders. On the higher plains (altitude 800-1100 masl), farming systems are mainly based on lowland rice and extensive livestock production. In other more remote areas, particularly at the highest altitudes (900-1200 masl), upland rice production is the

Comparative indicators (MAF 1999) reported that the socio-economic paths of the uplands and of the Mekong corridor diverged from 1994 to 1998 following modification of the agricultural sector and rural economic growth. During the 1994-1998 period, the mean value of household assets stood at US\$471 for the Mekong corridor and \$247 for the uplands, while this value had been equal (\$240) in both locations from 1986 to 1993. Some places, like southern Xayabury, experienced significant rural growth related to Thai market demand. However, even very good soils with high potential for agricultural development can be rapidly degraded. Such damage to natural resources and cultivated area has immediate negative social and economic impacts (Photo 1).



A Holistic Research Approach to Generate, Adapt and Validate Technologies with Smallholders

This approach, based on knowledge of local farming systems and environmental conditions such as morphopedological formations, access to market, credit, and inputs, is composed of five components (Séguy *et al.* 1998):

- ⊙ Initial assessment: agro-economic and social diagnosis of farming systems, human and physical environments provides a basis for generating technologies adapted to smallholders' strategies and environmental conditions.
- ⊙ Setting up medium-term experimental units where conventional systems are continuously compared with DMC systems based on available technologies, and innovative DMC systems based on new technologies and inputs.
- ⊙ Adaptation and validation by smallholders of DMC systems and simple technologies:
 - On-farm implementation with farmer groups: agro-economic evaluation for labour requirement, production costs, yields, net income and labour productivity;
 - Community-based approach which focuses on the adoption of technologies at village level, taking into account collective land management.
- ⊙ Permanent training for smallholders, extension agents and information provision to policy makers.
- ⊙ Follow-up and analysis of the conditions of extension and adoption by farmers.

The third and fifth components have so far been implemented only in southern Xayabury, due to the more advanced situation in this location.

Initial Assessment

Initial assessment has been carried out at different levels in order to integrate all aspects of smallholder strategies and environmental conditions. The first step is based on data collection (province, district, extension services and village) and environmental diversity observations. Headmen and village councils are interviewed in each village to assess community practices and recent changes related to land tenure and agriculture. Information on market channels is obtained through interviews with agriculture officers, traders and village headmen. The second step records knowledge of farming systems in order to identify the advantages and constraints of present systems and to evaluate new technologies at farm level. Quantitative and qualitative household surveys are carried out on targeted farmer groups in order to acquire information on household conditions and farming systems. A total of thirty-one (eight villages) and seventy-four households (twenty-two villages) were surveyed in southern Xayabury and Xieng Khouang respectively.

Setting up Medium-Term Experimental Units and Diversification of Technologies

In both locations, and related to initial assessment, medium-term (at least four years) experimental units representative of the bio-physical (integrating soil, slope and climate) and farming systems diversities were set up in order to test a large range of cropping systems (actually eight, see Table 1) and technologies. Soil and crop management, cultivars, others inputs (fertiliser and/or pesticide) and natural conditions are cross-linked to obtain a set of highly varied conditions (Séguy et al. 1998). Four experimental sites have been implemented in each province with a total area of 15ha and 20ha in southern Xayabury and Xieng Khouang respectively. Throughout the trial, permanent comparisons are made among traditional cropping systems, which remain the reference, and different levels of DMC systems optimisation (Photo 2). Conventional systems are modified iteratively in order to evaluate each component's influence on system performance and to match smallholders' strategies in adopting technologies. In different experimental units, soil and crop management sets are conducted under different levels of fertiliser in order to assess the evolution of the different systems under time. Moreover, these units provide an excellent opportunity for researchers to analyse short, medium and long-term biological and physicochemical processes in stabilised systems.



Modification of Land Preparation and Crop Management

An iterative generation of DMC systems is followed in both locations. The first step is based on modification of land preparation with crop and weed residues management. Cash crops like Job's tears (*Coix lacryma Jobi*) and rice-bean (*Vigna umbellata*) can be considered as key crops for implementing this first level of DMC systems. These crops, with long-cycle durations, produce a large amount of dry matter (over 20t.ha⁻¹ for Job's tears) and degradation of these residues is relatively slow due to a high rate of lignin. This provides good soil protection, reducing evaporation, soil erosion and weed pressure (Photo 3). Moreover, the strong rooting system of Job's tears improves soil structure, making it a useful former crop. The second step integrates soil and crop management (association, rotation and/or annual crop sequence) in order to diversify the production (grain production, rational use of forages by grazing and/or cut and carry), and so reduce agronomic, economic and climatic risks while optimising the main functions of DMC systems through adequate use of main and relay crops.



Use of Cover Crops

Many options are available when using additional crops (cover crops) but in the case of smallholders, who usually lack of market access, an integrated cropping and livestock production system is more suitable. Many systems are being tested in experimental units or with smallholders in both locations:

- Rotations with direct-seeded grain crops (maize, Job's tears) followed by forage production for grazing (Kluthcouski et al. 2000). Species like *Brachiaria ruziziensis* are sown at the first weeding stage by seed broadcasting in order to limit labour input. After two or three years, depending on the farmer's strategy, crops can be direct seeded on forage mulch.

- ⊙ Association of cash crops (maize or Job's tears) with living cover crop (*Centrosema pascuorum*, *Desmodium uncinatum*).
- ⊙ Mixed system between edible crops and *Brachiria ruziziensis*, frequently slashed and imported in the row to protect the soil, control weeds and improve nutrient availability for the main crop via mulch mineralization.
- ⊙ Regeneration of grasslands (altitude plains in Xieng Khouang province) by use of forage species (*B. ruziziensis*, *B. mulatto*, *B. brizantha*). One of the main functions of *Brachiararia* sp. is to improve soil structure and recycle nutrients leached deep in the soil through strong and deep root systems. After two or three years of biological improvement, upland rice can be direct seeded on forage mulch.
- ⊙ Grain production based on two crop sequences: a main short-cycle crop (e.g. peanuts, sesame, soybeans) followed by a relay crop for small animal feeding (sorghum, finger millet, oats in winter in mountainous areas). The aim of this system is to use annual species which can produce grain and a high amount of dry matter at the end of the rainy season.

Location and systems	Crop management: rotations, associations and crop successions		Main products	Advantages	Weak points
Grain production in southern Xayabury and Xieng Khouang	Annual cropping	Maize / Maize	Grains for agro-industry	- Lower production - Higher net income	- Weed control and soil erosion
Southern Xayabury – Large scale rainfed grain production	Rotational sequence, two years	Maize / rice-bean		- Higher net income, yields and labour productivity - Control of weed and soil erosion	- Erratic grain production of rice-bean
	Rotational sequence, three years	Job's tears / rice-bean / upland rice	Grains for agro-industry and home consumption	- Control of weeds and soil erosion - Soil structure and fertility - Higher net income, yields and labour productivity	- Small market for Job's tears - Erratic grain production of rice-bean
Mountainous area in Xieng Khouang	Mixed system	Maize / Legumes or upland rice – <i>B. ruziziensis</i> (slashed and imported in the row)	Grains for home consumption and integration with livestock production	- Control soil erosion and weeds - Improve soil fertility - Integration with livestock production - Forage seed production	- Need fertiliser to compensate for nutrient exportation by forage - Labour inputs
Altitude plains of Xieng Khouang	Rotational sequence, three to four years	<i>Brachiararia</i> sp. (2-3 years) / upland rice (1-2 years)	Edible crop for home consumption and integration with livestock production	- Regeneration of waste lands - Added output with forage seeds production - Livestock production	- Need economic incentives - Inputs and specific tools (direct sowing machine for hand tractor)
Mountainous area in Xieng Khouang	Rotational sequence, three years	Maize / Soybean – oats in winter / upland rice	Grains for agro-industry, livestock production and home consumption	In progress	
Southern Xayabury		Job's tears - <i>B. ruziziensis</i> - <i>C. Cajun</i> / rice-bean / upland rice			
Southern Xayabury and mountainous area in Xieng Khouang	Living mulch	Maize - <i>Centrosema pascuorum</i> or <i>Desmodium uncinatum</i>	Grains for agro-industry and for livestock production		

Table 1: Example of some DMC systems generated in southern Xayabury and Xieng Khouang province.

Adaptation and Adoption by Smallholder Groups through a Community-Based Approach in Southern Xayabury

Adaptation and Validation at Farm Level

The third component of this holistic approach uses on-farm adaptation and validation of the first level of DMC systems that match smallholders' conditions and strategies. In this region, agricultural developments copied from Thailand: crop residues and weed mulch are usually burned, thereby increasing mineral losses and erosion on bare soil. This generates land erosion, fertility losses and yield decrease. In addition, because of the environmental and financial costs of land preparation, farmers are shifting to herbicides, which are sprayed before and/or after crop emergence, and so lead to chemical pollution. These developments are leading to the destruction of paddy fields and even roads, as the degradation of agricultural land has serious knock-on effects downstream. Many farmers have now requested technical support to modify land preparation.

Experience has shown that organisation of farmers through groups is crucial for the adaptation and adoption of DMC systems, which modify mostly conventional agriculture (Landers 1998). Farmers groups were organised for a total of 42 families in southern Xayabury (six villages) to validate technical options aimed at decreasing production cost and labour, and limiting rainfed area erosion. DMC systems for crop residues are implemented for cash crops such as maize, Job's tears and rice-bean. A few modifications to cropping systems are proposed to smallholders in order to set-up, adapt and validate each step using current crops and cultivars. DMC systems for crop residues can exhibit very good results (Photo 4) in terms of net income, yield and labour productivity (Tivet et al. 2004; Tran Quoc et al. 2005). Referring to feed-back from smallholders, every constraint is notified during the process of adaptation and adoption and taken into account into the experimental unit. Tran Quoc et al. (2005) give a review of the main constraints identified by men and women in farmer groups.



Community-Based Approach

Dealing with community land management is essential in order to scale-up DMC systems. Maintaining crop residues or cover crops on fields is a difficult process where land management modification has to occur during the dry season. Wild fires that are started by farmers and spread to the land of other farmers are common. One option proposed by the programme, as suggested by Sain and Barreto (1996), is to enhance the attractiveness of mulch, linking this component to other technological changes that tend to decrease production costs while increasing cash income and labour productivity.

In four villages where farmer groups have been constituted, a research development programme has been set up to work along the following lines recommended by Chazée (1994):

- ⊙ Analysing the short- and medium-term strategy of the village.
- ⊙ Analysing needs relating to the work developed by the programme and others needs.
- ⊙ Formalisation of a research and development programme with the community.
- ⊙ Definition of the activities which will be implemented with the community.
- ⊙ Encouraging, from the beginning, the continuation of this research-development process with farmers, headmen, and district and provincial agricultural services after the end of the programme.

This framework seems essential to understanding the effects and impacts of our activities, and particularly to understanding the whole *problématique* at the village level. At this time, ninety-seven smallholders are adapting DMC systems (over approximately 78ha) based on residue management in the context of the constraints of their farming systems and overall environmental and economic conditions. Others technologies, such as regeneration of pasture lands with improved forage species (*Brachiaria* sp.), have been adopted by sixty families and cover more than 65ha.

Issues and Challenges in Scaling-Up DMC systems in Laos

Economic Incentives

Economic incentives such as provision of credit have to be promoted. As observed in southern Xayabury and reported also by Petersen et al. (1999), one of the major limiting factors to adoption may be that the practice promoted was first perceived as being closely associated with a need to use cash income for equipment and inputs. In southern Xayabury, traders give ploughing and seed credit at the beginning of the season. For many smallholders, even if high interest rates (50% over eight months) are used, this function is positive as it gives them the opportunity to not use any cash. In mountainous areas and altitude plains, new farming systems based on DMC integrated with livestock and forestry products could be stable and profitable if, at the same time, economic incentives (access to market, inputs, credit, agriculture and forestry product processing) are promoted to allow this development.

Mechanisation

It should be noted that labour force is one of the main limiting factors in agriculture, and smallholders cite three main objectives in their development goals: i) increasing cash income and cultivated area, ii) labour optimisation and iii) decreasing the drudgery of labour. Specific tools, such as the hand-jab seeder, the direct sowing machine for hand tractors, and low-volume application sprayers, can reduce drudgery and labour inputs. Smallholders are currently highly dependent on traders who own tractors, and their choice of land preparation is somewhat dictated by the burden of borrowing. Increased mechanisation in the area, with an increase in the number of hand tractors and tractors, would increase the ability of farmers to farm their land on a more sustainable basis.

Biomass Management at Community Level

As mentioned above, rules must be defined at the community level for management of cover crops and residues during the dry season. Managing the interface between animal and crop components is crucial to the success of these systems. Overgrazing of cover crops or crop residues during the dry season may leave too little mulch for sowing the following wet season crop, thereby affecting the main functions of the DMC systems. Specific forage use and control of wild fires must be defined by the community.

Land Tenure and Amount of Cultivated Area per Household

This approach, based on soil conservation technologies and integration of systems (livestock and perennial crops), can be efficient in the uplands if land tenure per household is defined under specific conditions. Obviously, land allocation must be flexible, taking into account the diversity of livelihoods in the uplands. Maintaining and protecting soil resources and biodiversity will be effective if enough land is allocated to smallholders for the integration of forestry area and natural resource uses.

Improvement of the “Smallholders, Researchers, Extension Agents, Decision-Makers and Private Sector” Continuum

The different components of this approach generate a strong training environment for smallholders, research and extension officers, and all of the stakeholders involved in development. However, this continuum has to be improved in order to share experience and to efficiently disseminate DMC systems. The main limiting factors are a lack of extension officers at provincial and district level; lack of human resources to give the available technical information in a way that is understandable for each stakeholder; and a low level of coordination between all the stakeholders. The Lao government and its Ministry of Agriculture and Forestry recently recognised that this approach should be scaled up at nationally in order to protect natural resources, maintain soil potential and increase livelihoods. Moreover, it has been proposed that a specific degree course on DMC systems be developed in the agricultural schools where the country's extension officers are trained.

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Example of an Iterative Approach Conducted with Smallholders in Northern Laos for the Adoption of Direct-Seeding Mulch-Based Cropping Systems



Rice-bean (*Vigna umbellata*), Paklay district. Photo by P. Grad

Authors: Hoà Tran Quoc, Florent Tivet, Chanthasone Khamxaykhay, Piane Chanthip, Bounsay Chantharath, Patrick Julien and Lucien Séguy

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Hoà Tran Quoc¹, Florent Tivet¹, Chanthasone Khamxaykhay², Piane Chanthip³, Bounsay Chantharath², Patrick Julien⁴ and Lucien Séguy⁵

1. CIRAD-CA, PO Box 2991, Vientiane, Lao PDR, E-mail: ciradca@laotel.com
2. NAFRI, PO Box 811, Vientiane, Lao PDR
3. Provincial Agriculture and Forestry Office, Xayabury Province
4. Local consultant, PO Box 749, Luang Prabang, Lao PDR
5. CIRAD-CA, Goiânia, Goiás, Brazil, E-mail: lucien.seguy@cirad.fr

Abstract

Since the 1990s, in the southern districts of Xayabury province in the Mekong corridor, traditional farming systems have changed through extensive agricultural development based on cash-crop production. This development, by way of intensification, depends on local market accessibility, transfer of technologies from Thailand and the financial capacities of local enterprises. Thai Inputs, heavy mechanisation and technical skills are imported and cropping is largely opportunistic, following Thai market demand. Land preparation, based on burning residues and ploughing on steep slopes, has allowed for cultivation of large upland areas. As a result of this development, combined with land allocation and increasing population density, fallow periods are disappearing. Furthermore, this ‘resource-mining’ development generates land erosion, fertility loss, yield decline and chemical pollution as well as destruction of roads and paddy fields. In light of this, the Lao National Agro-Ecology Programme has implemented a holistic research approach in order to propose various systems for integrating crops and livestock production to farmers. From a large range of technologies that were tested, maize production using direct seeded grain on former crop residues under no-tillage systems has been implemented. Results achieved under the various conditions are presented in this paper: the yields obtained are close to and sometimes even higher than those obtained in conventional systems. Labour, costs, net income and labour productivity are also all observed.

Media summary

Direct-seeding mulch-based cropping systems are compared with conventional practices in southern Xayabury through on-farm experiments. Promising results are obtained with this first level of DMC systems, mainly based on use of available technologies for smallholders. Feedback from farmers also identifies the main constraints of these systems.

Keywords

Xayabury province, iterative approach to soil conservation, residue management, labour productivity, key factors for scaling-up.

Introduction

Traditional farming systems have drastically changed over the last fifteen years in the southern districts of Xayabury province, with considerable agricultural development based on the production of cash crops such as maize, rice-bean (*Vigna umbellata*), peanuts, Job’s tears (*Coix lacryma*), black cowpeas (*Vigna unguiculata*) and sesame. This development, by way of intensification, depends mainly on local market accessibility, transfer of technologies from Thailand and the financial capacities of local enterprises (to fund inputs, heavy mechanisation and technical skills from Thailand). Due to its low labour requirements and high labour productivity, maize is widely sown and spreads to new areas every year (more than 15,000 ha was sown in southern Xayabury in 2004), while crop rotation tends to be abandoned. Land preparation based on burning residues and ploughing on steep slopes has allowed for cultivation of large upland areas.

As a result of this development, associated with land allocation and increasing population density, fallow periods are disappearing and agricultural systems are not conserving soils and nutrients. Even arable land with very good soils and high potential for agricultural development can be rapidly degraded, in which case negative social and economic impacts follow. Initial assessment of this 'resource-mining' agricultural development shows dramatic land erosion, and destruction of roads and paddy fields. In many degraded areas of southern Xayabury, smallholders have modified conventional land preparation and are shifting from ploughing to herbicides. Residue burning, followed by spraying before sowing, is common. Increasing use of pesticides is also one of the major issues of this agricultural intensification. Herbicides such as Atrazine, Paraquat and Glyphosate are now widely used in southern Xayabury for land preparation after burning or ploughing (sometimes up to 10l.ha⁻¹ of Paraquat or Glyphosate) and for post-emergence application (Atrazine) on maize. It is estimated that in 2004 more than 90% of smallholders in Parklai district used Atrazine.

These changes in agricultural practices emphasise the great reactivity, good or bad, of smallholders, who cite three main objectives in their development goals: (i) cash income and increasing the area cultivated, (ii) labour optimisation and (iii) decreasing the drudgery of labour. In order to convert this 'resource-mining' production to a stabilising plant-soil system, an iterative approach has been implemented to analyse, for each step, the technical and socio-economic viabilities of direct-seeding mulch-based cropping (DMC) systems. The aim of this paper is to compare maize production under direct-seeding on crop residues with production through conventional land preparation, mainly based on ploughing. Since 2002, the Lao National Agro-Ecology Programme has implemented a holistic research approach which emphasises generation and adaptation of DMC systems with village communities and groups of smallholders.

Methodology

On-Farm Experiments

The main characteristics of this region are given in Bounthong et al. (2005). Farmers' field experiments are carried out on plots of at least 4,000m². Comparisons between conventional and DMC systems are assessed on large demonstration plots under conditions that match those found on farms in the region. Wherever possible, conventional land preparation is replicated on both sides (1,000m² x 2) of the direct-seeding plots (2,000m²) and arranged on landscape slopes in order to take fertility gradients into account. These experiments involve 42 smallholders located in six villages with a total area of 16.8ha. Comparisons are also carried out between DMC systems on residues and conventional cropping systems for different edible and cash crops. The results discussed in this paper concern maize, the main production crop in this region. The number of fields differed according to zone (with varying morpho-pedological features, access to market and farmer strategies) with six, four, eleven, three, five and five fields used in Kengsao, Bouamlao, Paktom, Nahin, Houay Lod and Nongphakbong respectively. A description of the different steps followed for land preparation for DMC systems is given in Figure 1.

Data Collection and Economic Analysis

Labour requirements and production costs were recorded for all activities (land preparation, sowing, weeding and harvesting). Yield and overall performance is recorded for each treatment. However, the philosophy under which the experiments were carried out allows for qualitative analysis in order to evaluate the socio-economic viability of these systems.

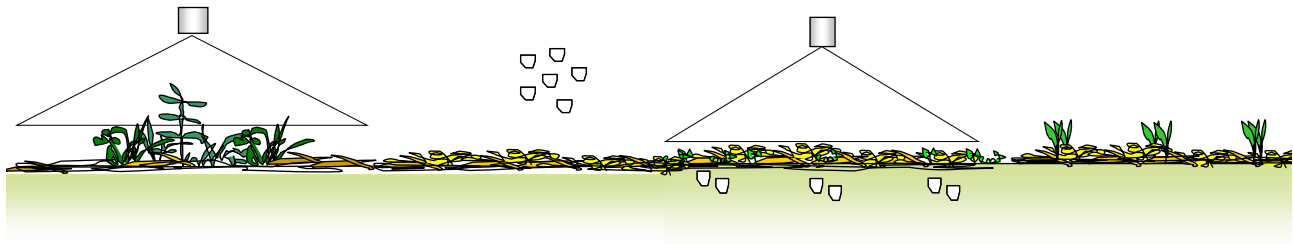


Figure 1: Description of the different steps followed for land preparation under DMC systems with residue management. Choice of herbicide depends on weed pressure and the nature of weeds in the field.

Results and Discussion

Mulch Remaining before Sowing

A layer of mulch, even a thin one, limits soil erosion by decreasing the kinetic energy of raindrops and run-off intensity (Abrahams et al. 1994). Moreover, run-off intensity is decreased because of the sinuous pattern that is generated by residues. This wavy pattern increases the path and decreases the effective slope met by the run-off. Findeling (2001) reported that 4.5t.ha^{-1} of dry matter can represent a 30% slope reduction and reduce run-off intensity by 20%. At the beginning of the rainy season in 2004, dry matter ranged from 2.0 to 3.5t.ha^{-1} . However, this figure refers only to large particles of residue and ignores small aggregates of soil and straw, which also greatly reduce run-off intensity. After harvesting, large amounts of dry matter are obtained with these different cash crops (maize, rice-bean and Job's tears). For example, on average the dry matter reaches 16t.ha^{-1} with Job's tears, 8t.ha^{-1} for maize, and 6.5t.ha^{-1} for rice-bean under good soil potential. Mulch remaining at the beginning of this season (2005) represented at least 45% of the dry matter recorded after harvesting, with no exportation by animals occurring during the dry season.

Crop residue management can be a first step towards reducing losses of soil and mineral elements, as well as a way of saving money. In southern Xayabury, Job's tears and rice-bean are useful crops for starting DMC systems on residues because of: i) their low residue degradation due to a high lignin content, which enhances soil protection by reducing both evaporation and weed pressure (particularly for rice-bean); ii) the low rate of C/N for rice-bean residues, minimising mineral nitrogen competition between the crop and micro-flora at the beginning of the rainy season; and iii) the low level of animal exportation owing to the low palatability of both species. Below-ground dry matter was not measured, but biological improvement of soil structure by rooting systems is crucial. A crop of Job's tears with long duration and a strong rooting system is a good companion crop for ensuring this function.

Yield

For each treatment, grain yield variations for maize, according to site characteristics (landscape, soil units) and cultivars are significant (Table 1). Such results reflect differences in soil erosion and fertility. For example, while Paktom, Nahin and Bouamlao have the same geological substratum, large differences in yield are observed. In southern Parklai (Kengsao and Bouamlao) and northern Kenthao (Houay Lod), areas which began maize production recently, yields recorded under DMC systems reach 5t.ha^{-1} . With DMC systems, yield levels were generally close to or even higher than those obtained in conventional systems, with no substantial difference observed. In Northern Kenthao, the use of fertiliser can increase yield by up to 37%, which can counterbalance production cost. In contrast, the use of fertiliser does not appear to be economically viable for degraded areas like Nongphakbong and Nahin. However, use of fertiliser under direct-seeding tends to boost not only yield but also biomass production, thus indirectly enhancing soil biological activity. In these degraded areas, the mean average yields recorded with no-tillage oscillate between 2.3 and 3.4t.ha^{-1} with maize, while mean yield with tillage is 3.3t.ha^{-1} . In Nongphakbong, poor soil structure due to soil compaction and soil crusting seems to be the main limiting factor of yield under both DMC and conventional systems. Erenstein (2003) reported that short-term yield effects often depend on the mulch, crop and site characteristics. Therefore a number of seasons are necessary to stabilise the system. As described by Séguy et al. (1998), soil characteristics must be improved in order to generate a conservative system for water and nutrients with good organic composition to restructure the soil. Moreover, enhancement of soil biological activity is crucial as below-ground insect and microbial populations improve soil structure and plant nutrition. Because of the great modifications of the soil by conventional agriculture, these main functions can be completed under medium and long-term processes.

Production Cost and Net Income

High variations are observed in economic components such as production costs, net income and labour productivity, mainly dependent on the number of replications and on site characteristics (Table 1). An example cost production analysis for southern Parklai is given in Figure 2. For ploughing, production costs ranged from US\$40 to \$150 per ha depending on the slope, distance from the main road, and amount of stones and/or stumps in the field. In comparison, the cost of land preparation with DMC systems is about \$30 per ha. Production costs can therefore be reduced by 30%-100%, representing a gain of \$35-\$100 per ha (Table 1). In southern Parklai (Kengsao, Bouamlao) and northern Kenthao (Houay Lod), net income per ha was highly significant with a mean value close to US\$ 250 per ha for direct-seeding. The difference in income between this method and the conventional approach varied from \$45 to over \$150 per ha. Furthermore, results emphasise that in these zones the use of mineral fertiliser is economically viable because of good soil fertility and lower weed pressure.

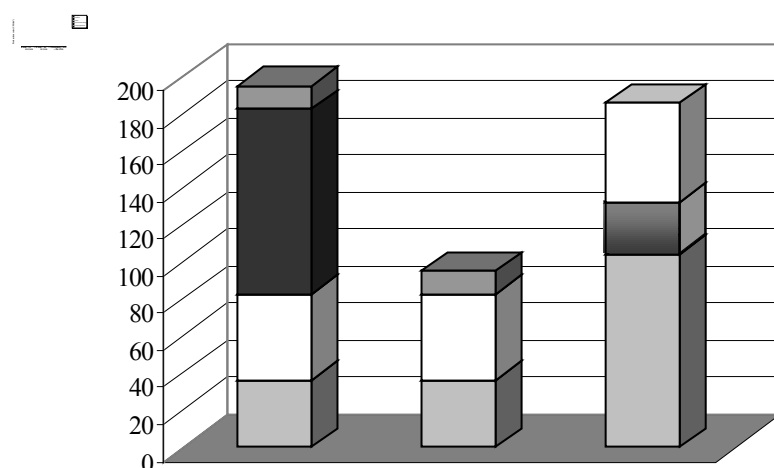


Figure 2: Production costs analysis in southern Parklai. A mean of eleven replications is given

Labour Requirements and Labour Productivity

With direct-seeding technologies and a reasonable mulch layer before sowing (at least 3t.ha^{-1}), weed pressure was lower than in conventional situations. Figure 3 shows that labour inputs required for weeding is only 3 days. ha^{-1} with no tillage and 31 days. ha^{-1} with tillage. A total mean gain of 39 days/ha was recorded during the season for DMC systems. Labour inputs for weeding depend greatly on the history of the field and on the nature of the former crop. Local species like rice-bean and Job's tears are ideal crops to start a direct-seeding system. With long-cycle duration (seven months), both species compete fiercely with weeds during the rainy season and produce a high amount of biomass.

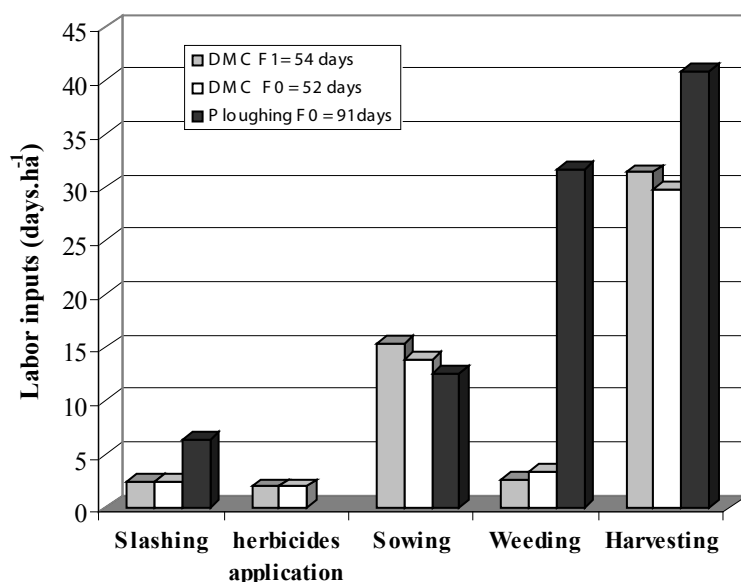


Figure 3: Labour inputs in southern Parklai and northern Kenthao. A mean of seven replications is given (quantity of remaining crop residues is superior to 3t.ha^{-1}). Labour inputs for threshing and transport are not represented. Sowing was carried out without the use of a hand-jab seeder.

Little data was recorded in the field, but both a decreasing number and a change in species of weeds is common in the second year of direct-seeding. In southern Parklai, with residue management, *Ageratum conizoides* become the dominant species and *Mimosa invisa*, which is the major weed associated with ploughing and burning, is significantly reduced. Dominance of this species in the conventional system is mainly related to the fact that burning tends to boost seedling emergence (Lao-IRRI 2000).

In all fields, labour productivity increased with residue management. This was most notable in Bouamlao, Kengsao and Houaylod (Table 1), where the increase ranged from \$4.2 to \$4.8 per day (DMC F0). In contrast, in the most degraded areas like Nongphakbong, very low labour productivity ($<\$1/\text{day}^{-1}$) is recorded under both DMC systems and conventional land preparation. These results are mainly due to the combination of low yields and the very low selling price of maize in this area.

Main Constraints for this First Step, Based on Residue Management

In southern Parklai, where area of maize cultivated per labourer can reach 2.5 ha, land preparation through large-scale herbicide application represents a considerable labour drudgery for men. Women meanwhile are more concerned about labour during sowing, and the risks of men becoming poisoned when using herbicides. Traders and/or tractor-owners give ploughing and seed credit at the beginning of the season. For many smallholders, even if higher interest rates are practiced (50% over eight months) such loans offered a good opportunity to avoid using any cash at the beginning of the season. The current lack of cash was identified as one of the major constraint, and was also cited by both men and women in Houay Lod, where no-tillage practice is common. Problems relating to labour input are also frequently emphasised following the drastic increase of cultivated area in this village. On the other hand, in degraded sites like Nongphakbong and Paktom, constraints relating to sowing through crop residues seem to be more important (including soil compaction induced by former ploughing, and difficulty in making holes and in seeing them through the residue crops).

Components	Treatment	Villages									
		Kengsao		Bouamlao		Houay Lod		Paktom		Nahin	
	Year	2003 (3)	2004 (6)	2003 (5)	2004 (4)	2004 (6)	2003 (8)	2004 (11)	2003 (2)	2004 (3)*	2004 (4)
	Replication										
Yield (kg/ha)	DMC F0	5481	4583	5044	3727	4976	2563	3383	2507	2796	2270
		± 167	± 325	± 379	± 379	± 435	± 329	± 714		± 559	± 434
	DMC F1	7542	6106	7413	5657	6779	3616	5356	3769	3876	3960
		± 693	± 338	± 451	± 827	± 437	± 268	± 214		± 98	± 91
	CV F0	4332	5215	5073	4629	4726	2787	3477	3438	-	3305
		± 691	± 588	± 281	± 394	± 518	± 316	± 42		-	± 811
Production cost (US\$/ha)	DMC F0	116	100	93	90	94	52	89	46	44	59
		± 13	± 12	± 3	± 3	± 0.5	± 5	± 9		± 7	± 14
	DMC F1	220	200	198	190	194	145	189	153	172	189
		± 13	± 12	± 3	± 3	± 1	± 11	± 9		± 5	± 14
	CV F0	169	201	142	185	194	88	111	84	-	86
		± 39	± 40	± 23	± 46	± 61	± 8	± 16		-	± 28
Net income (US\$/ha)	DMC F0	227	243	222	236	280	82	123	84	166	33
		± 19	± 53	± 23	± 67	± 73	± 17	± 8		± 32	± 41
	DMC F1	252	258	265	305	315	43	146	43	119	- 27,4
		± 53	± 53	± 27	± 145	± 73	± 11	± 17		± 16	± 25
	CV F0	102	190	175	190	100	57	107	95	-	52
		± 53	± 84	± 39	± 86	± 41	± 19	± 16		-	± 66
Labour inputs (days/ha)	DMC F0	62	51	55	49	65	61	40	64	51	31
		± 5	± 8	± 9	± 13	± 10	± 4	± 12		± 19	± 1
	DMC F1	65	54	65	51	65	67	55	65	54	55
		± 2	± 7	± 9	± 13	± 10	± 5	± 9		± 14	± 13
	CV F0	75	93	70	64	78	74	41	93	-	64
		± 7	± 32	± 6	± 18	± 24	± 7	± 7		-	± 4
Labour productivity (US\$/day)	DMC F0	3.7	4.8	4.0	4.9	4.2	1.3	3.2	1.3	3.4	1.0
		± 0.1	± 0.9	± 0.8	± 1.0	± 0.9	± 0.2	± 1.4		± 2.0	± 0.8
	DMC F1	3.9	4.8	4.1	5.8	4.7	0.6	2.8	0.7	2.3	-0.5
		± 0.8	± 0.8	± 1.4	± 1.5	± 1.0	± 0.2	± 0.4		± 0.8	± 0.5
	CV F0	1.4	2.2	2.5	3.0	1.3	0.8	2.6	1.0	-	0.8
		± 0.7	± 1.3	± 0.7	± 1.5	± 0.1	± 0.3	± 0.5		-	± 0.6

Table 1: Data ± SE from on-farm experiments conducted in 2003 and 2004 in southern Xayabury. Mean value. Yield, Production cost, Net income, Labour inputs and Labour productivity are presented for five situations. Data is from three to eleven on-farm trials of 1000 m² per treatment.

Key: DMC: direct-seeding with residues management; CV: conventional ploughing; F0: without mineral fertiliser; F1: 400 kg.ha⁻¹ of 15-15-15. Nahin 2004*: all conventional plots were managed with crop residues.

Different constraints limit the dissemination of these systems even if agronomic and economic successes have been highlighted. A gender-disaggregated survey was carried out with all groups of smallholders to identify the main constraints of this first level of DMC systems on residues (Figure 4). The results of this survey emphasised the main limiting factors:

- ⊙ Drudgery of labour for land preparation (herbicide application), which limits cultivated area;
- ⊙ Access to inputs (market and financial constraints, such as lack of cash);
- ⊙ Problems of appropriate equipment for sowing;
- ⊙ Technical skills required;
- ⊙ Calendar flexibility;
- ⊙ Risks of damage due to pests (rodents, insects);
- ⊙ Risks of human intoxication by misuse of pesticides.

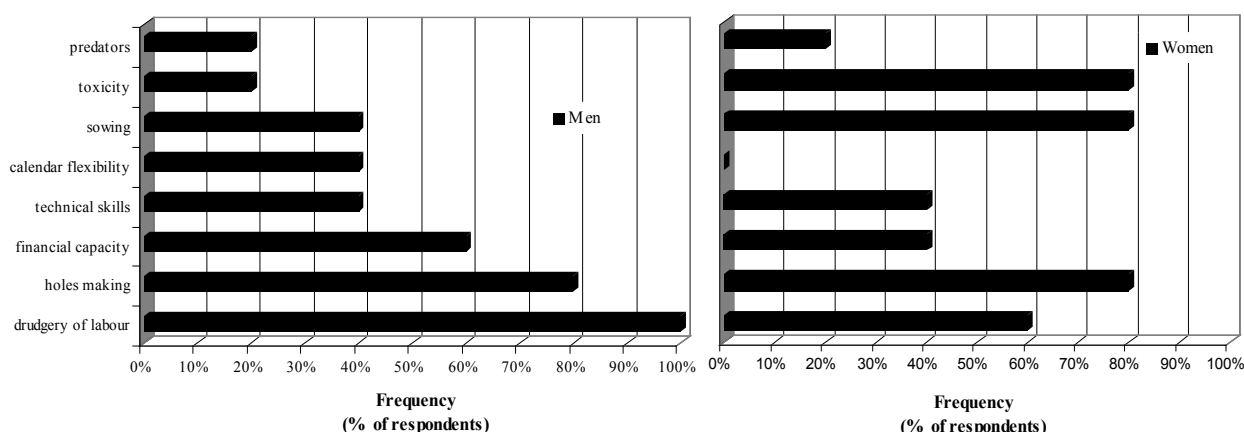


Figure 4: Factors limiting extension of DMC systems, as identified by smallholders in Kengsao

Issues and Challenges for Dissemination of DMC Systems in Southern Xayabury

Positive results from direct-seeding systems based on residues are evident in southern Xayabury. The area also displays both a growing interest in and the potential for widespread adoption, with many smallholders requesting technical and financial support. However, obtaining all the biophysical and economic advantages of DMC systems involves a long process. The amount of residues remaining on fields is often relatively low due to biomass weathering, animal exportation, or even sometimes wild fires during the dry season. Small amounts of residue do not ensure good soil protection and/or weed control. In order to efficiently control weeds (through a smothering and/or allelopathic effect) and thereby generate systems that are less dependent of herbicides (Séguy 1999; Kliever 2003), DMC systems have to be progressively improved with rational crop rotations, relay crops and cover crops.

In order to promote the extension of these systems, the limitations already identified by smallholders should be rapidly minimised through a series of actions:

- ⊙ Adequate equipment for DMC systems should be adapted on several scales in order to decrease labour drudgery. Diversified direct-seeding equipment, such as the sowing machine for hand-tractor and medium tractor, has been designed in Brazil and could be adapted and distributed in southern Xayabury.
- ⊙ Economic incentives such as provision of credit have to be promoted by decision makers and development projects.
- ⊙ As knowledge is continuously generated in the field by researchers and farmers, it is essential that continuous training sessions be organised in order to share experience on the adaptation and adoption of such systems.
- ⊙ As reported by many authors, the use of pesticides (herbicides and insecticides) can decrease rapidly under DMC systems with appropriate use of mulching and cover crops (Jansen 1999; Crovetto 1999; Scopel 2003). In the case of smallholders however, special attention must be addressed to the use of pesticides. Lack of knowledge leads to frequent misuse of pesticides, particularly in handling, with dramatic consequences for human health and the environment. In addition, with widespread herbicide use, large concentrations of pesticides can pollute rivers and soil. Products, which can be used as substitutes, should be researched.

Acknowledgement

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Improving Smallholder Soil Management and Livelihoods in Northern Laos through Conservation Agriculture



Left, direct seeding of maize on crop residues, right, maize after ploughing. Photo by H. Tran Quoc

Authors: Florent Tivet, Hoà Tran Quoc, Pascal Lienhard, Bounsay Chantharath, Khamkèo Panyasiri, Patrick Julien and Lucien Ségué

Improving Smallholder Soil Management and Livelihoods in Northern Laos through Conservation Agriculture

F. TIVET, H. TRAN QUOC, P. LIENHARD, B. CHANTHARATH, K. PANYASIRI, P. JULIEN and L. SEGUY

Context and objective

Farming systems throughout Laos have changed drastically over the last 15 years. Where market forces are prevalent (e.g. in southern Xayabury), shifting cultivation systems have given way to more conventional high-input agricultural systems. In other, more remote areas such as Xieng Khouang province, traditional swidden systems have been put under pressure by modification of land access and increasing population pressure. Intensification of shifting cultivation has rendered these systems unable to face the main challenges of food security, soil and water conservation and environmental protection. Maintaining productive capacity of the soil is a crucial element for long-term improvement of livelihoods. NAFRI and CIRAD have implemented a holistic research approach and an iterative process of generating direct seeding mulch-based cropping (DMC) systems with smallholders.

A Holistic Research Approach to Promote Soil Conservation Technologies with Smallholders

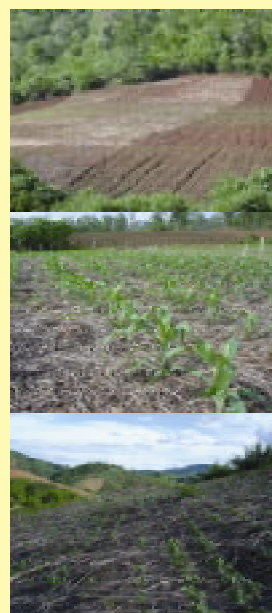
This approach, based on local farming systems and environmental conditions, comprises five components:

- Initial assessment to generate technologies adapted to smallholders' strategies and environmental conditions.
- Setting up medium-term experimental units, in which conventional systems are continuously compared with DMC systems.
- Adaptation and validation by smallholders of DMC systems and other technical alternatives:
- On-farm implementation with farmer groups.
- Community-based focus on adopting technologies at village level, taking into account collective land management.
- Permanent training of stakeholders.
- Follow-up and analysis of extension and adoption by farmers.



Medium-Term Experimental Units for DMC Systems

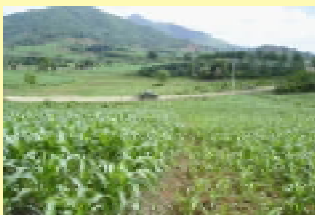
In Xieng Khouang and southern Xayabury, medium-term experimental units were set up to test a large range of cropping systems and technologies. Soil and crop management, cultivars, fertiliser and pesticide inputs and natural conditions are cross-linked to obtain a set of highly varied conditions. Continual comparisons are made among traditional cropping systems, which remain the reference, and between different levels of DMC system optimisation.



Adaptation and Adoption by Smallholder Groups through a Community-Based Approach

Adaptation and Validation at Farm Level

A process of on-farm adaptation and validation is used to match DMC systems to smallholders' conditions and strategies. Experience has shown that organising farmers into groups is crucial to this process. Farmers groups were organised for 42 families in southern Xayabury to validate techniques aimed at decreasing production cost and labour, and limiting erosion. Modifications to cropping systems are proposed and then each step is set-up, adapted and validated using current crops and cultivars. Feed-back from the smallholders is recorded throughout the process, so that every constraint can be taken into account during the experimental phase.



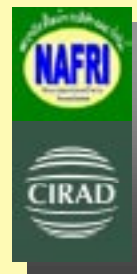
Community-Based Approach

A community-based land management approach is essential to scaling-up DMC systems. Maintaining crop residues or cover crops on fields is difficult where land management modification occurs during the dry season. One option is to enhance the attractiveness of mulch, linking this component to other technological changes that tend to decrease production costs while increasing cash income and labour productivity.

Challenges in scaling-up DMC systems

DMC shows positive results, but getting all the biophysical and economic advantages from these systems involves a long process:

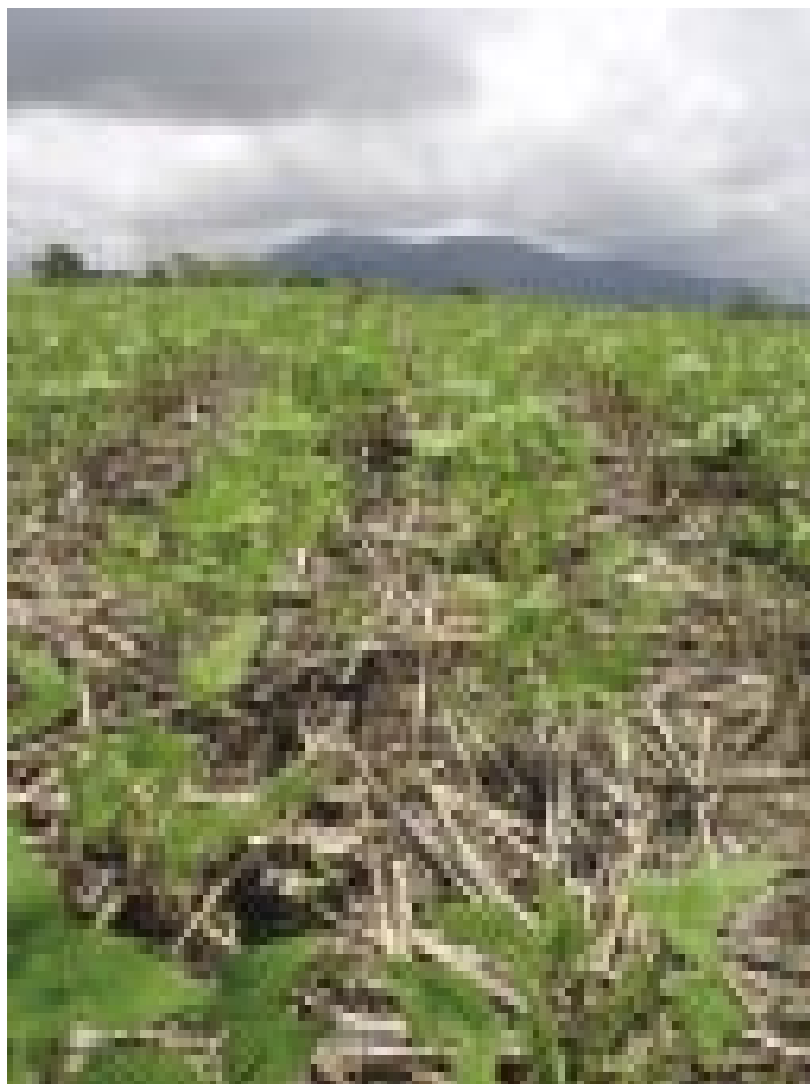
- Economic incentives have to be promoted. A major limitation on adoption may be that the practice was first perceived as requiring cash income for equipment and inputs.
- Specific tools have to be promoted to reduce drudgery and labour inputs.
- Rules must be defined at community level for management of cover crops during the dry season.
- Land allocation must be flexible, taking into account the diversity of upland livelihoods.



Lao National Agro-Ecology Programme

PO Box 811, MAF-NAFRI, Lao PDR. email: ciradca@laotel.com. Tel/Fax: (856 21) 770027

Validation of Alternative Cropping Systems Based on No-tillage and Crop Residue Management



Rice-bean direct-seeded on Job's tears residues. Photo by H. Tran Quoc

Authors: Florent Tivet, Hoà Tran Quoc, Chanthasone Khamxaykhay and Bounsay Chantharath

Validation of alternative cropping systems based on no-tillage and crop residue management

Southern Xayabury, Lao PDR

F. TIVET; H. TRAN QUOC;
C. KHAMXAYKHAY and B. CHANTHARATH



Context and objectives

The main characteristics of this region are its integration with the Thai market and the transfer of technologies from Thailand. Since the 1990s traditional rotational cultivation has changed to extensive agricultural development based on cash crops such as maize, rice-bean, peanuts, Job's tears and sesame. Land preparation, based on burning residues and ploughing on steep slopes, has allowed for cultivation of large upland areas every year. Within a few years, this conventional land preparation generates heavy soil degradation and depletion of natural resources, and seasonal migration frequently occurs due to collapsing livelihoods. Farmers groups, including a total of 43 families, were formed in six different production areas to analyse the technical and socio-economic viabilities of direct seeding mulch-based cropping (DMC) systems.

Materials and Methods

On-farm experiments were conducted in 2003 and 2004 on maize production. Data is from two to eleven on-farm trials of 1000 m² per treatment. At the beginning of the rainy season, systemic herbicides (3 L/ha of glyphosate + 1.5 L/ha of 2,4-D, solution pH of 3) are applied to control existing weeds. Ten days after spraying, crops are sown using a hand-jab planter. Job's tears and rice-bean are useful crops for starting DMC systems on residues because of: i) their low residue degradation due to a high lignin content; ii) the low rate of C/N for rice-bean residues, minimising mineral nitrogen competition at the beginning of the rainy season; and iii) the low level of animal exportation owing to the low palatability of both species. Agro-economic data on labour inputs, yields, production costs, net income and labour productivity are all observed.



Results and Issues

Positive results are evident from these direct-seeding systems based on residues. Farmers display a growing interest in widespread adoption, with many smallholders requesting technical and financial support. However, various constraints limit dissemination of these systems.

Components	Villages (replications)	Kengsao		Bouamiao		Paktom		Nahin	
		2003 (3)	2004 (6)	2003 (5)	2004 (4)	2003 (8)	2004 (11)	2003 (2)	2004 (3)*
Yield (kg/ha)	DMC F0	5481	4583	5044	3727	2563	3383	2507	2796
	DMC F1	7542	6106	7413	5657	3616	5356	3769	3876
	CV F0	4332	5215	5073	4629	2767	3477	3438	-
Production costs (US\$/ha)	DMC F0	116	100	93	90	52	89	46	44
	DMC F1	220	200	198	190	145	189	153	172
	CV F0	169	201	142	185	88	111	84	-
Net income (US\$/ha)	DMC F0	227	243	222	236	82	123	84	166
	DMC F1	252	258	265	305	43	146	43	119
	CV F0	102	190	175	190	57	107	95	-
Labour inputs (days/ha)	DMC F0	62	51	55	49	61	40	64	51
	DMC F1	65	54	65	51	67	55	65	54
	CV F0	75	93	70	64	74	41	93	-
Labour productivity (US\$/day)	DMC F0	3.7	4.8	4.0	4.9	1.3	3.2	1.3	3.4
	DMC F1	3.9	4.8	4.1	5.8	0.6	2.8	0.7	2.3
	CV F0	1.4	2.2	2.5	3.0	0.8	2.6	1.0	-

Table 1: Data from on-farm experiments conducted in 2003 and 2004 in southern Xayabury for maize production. Data is from two to eleven on-farm trials of 1000 m² per treatment. Key: DMC=direct-seeding with residues management; CV=conventional – ploughing; F0=without mineral fertiliser; F1=400 kg/ha⁻¹ of 15-15-15. Nahin 2004*: all conventional plots were managed with crop residues.

A gender-disaggregated survey carried out with all groups of smallholders identified the following limiting factors during this first level of DMC systems on residues:

- Drudgery of labour for land preparation, which limits cultivated area.
- Access to inputs (market and financial constraints, such as lack of cash).
- Problems of appropriate equipment for sowing.
- Limited technical skills.
- Calendar inflexibility.
- Risks of damage due to rodents and insects.
- Risks of human intoxication by misuse of pesticides.



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Impact of Technologies and Market Access on Natural Resources and Farming Systems, Southern Xayabury



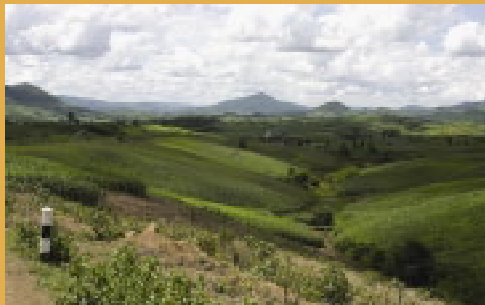
Soil erosion after ploughing and degradation of paddy fields in the lowlands in southern Xayabury. Photo by A. Chabanne

*Authors: Hoà Tran Quoc, Chanthasone Khamxaykhay,
Florent Tivet, Bounsay Chantharath and Khamkèo Panaysiri*

Impact of technologies and market access on natural resources and farming systems

Southern Xayabury, Lao PDR

H. TRAN QUOC; C. KHAMXAYKHAY;
F. TIVET; B. CHANTHARATH
and K. PANYASIRI



Context

Farming systems have changed drastically over the last fifteen years in southern Xayabury. Traditional farms have been transformed through development based on production of rainfed cash crops such as maize, rice-bean (*Vigna umbellata*), peanuts, Job's tears (*Coix lacryma*), black cowpea (*Vigna unguiculata*) and sesame. This development depends on local market accessibility, transfer of technologies from Thailand and the capacity of local traders to finance the import of inputs, heavy mechanisation and technical skills from Thailand.

Degradation of natural resources and destruction of roads and paddy fields

This development, associated with land allocation and increasing population density, has led to reduced fallow periods. As a result, agricultural systems are no longer conserving soils and nutrients. Even arable land with very good soils and high potential for agricultural development can be rapidly degraded.

Different strategies to suit each area

In areas with high soil fertility maize provides the main cash income for most households. Despite high yields (mean 5.0 t/ha), labour productivity is relatively low (mean US\$ 2.25/ha) because of high production costs (\$175/ha) incurred by ploughing, seed purchase, and chemical weeding.

In the most degraded areas a combination of multicropping, animal husbandry and off-farm activities gives a balanced distribution of farming activities over time and space. These strategies reduce climatic and economic risks in a fragile ecosystem.

Smallholders in this region cite three main development goals: (i) increasing cash income and the area cultivated; (ii) optimising labour; and (iii) decreasing the drudgery of work.

Converting this 'resource-mining' production

The region has experienced significant rural growth supplying the Thai market, but is now scarred by a rapidly degrading landscape. Such damage to natural resources and cultivated area has immediate negative social and economic impacts.

Awareness-raising exercises are urgently required and should focus on the economic costs of irreversible natural resource losses. The socio-economic factor is the starting point for generating and extending soil conservation technologies.

An iterative approach with farmer groups looks at the adaptation and validation of direct-seeding systems based on residue management and the positive features of local crops. Planned future systems will integrate soil and crop management to diversify production, for example through grain crops, and grazing/cut and carry forages. This will reduce agronomic, economic and climatic risks while optimising the main functions of DMC systems through adequate use of main and relay crops.



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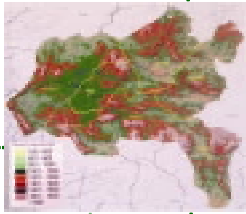
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Impact of Urban Development and Market Access on Farming System Evolution in Xieng Khouang, Lao



Market in Phonsavan, Xieng Khouang Province. Photo by P. Lienhard

*Authors: Pascal Lienhard, Guillaume Dangé,
Marie-Pierre Talon, Somchanch Syphanravong
and Thammakham Sosomphou*



Improving Feed Resources for Animals in Smallholder Farming Systems, Xieng Khouang Province, Lao PDR

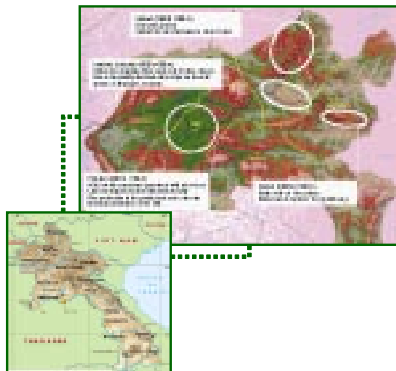


Collection of *Brachiaria decumbens* seed using bag-nets in Xieng Khouang. Photo by P. Grand

Authors: Pascal Lienhard, Thammakham Sosomphou, Sompheng Siphongxay, Florent Tivet and Lucien Séguy

Improving Feed Resources for Animals in Smallholder Farming Systems of Xieng Khouang

P. LIENHARD, T. SOSOMPHOU,
S. SIPHONGXAY, F. TIVET and
L. SEGUY.



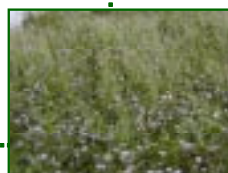
Feed options throughout the year

The Lao Government considers development of the livestock industry to be a priority, since cattle are an important export and the main source of monetary income for most farmers. Xieng Khouang province is of particular interest since an estimated 60,000 ha of acidic savannah grasslands around the provincial capital could be used to grow animal feed.

Improving forage access

Local seed multiplication contracts have been signed with farmer groups to improve both access to and interest in forages. Through these, the farmers can earn income by selling forage seeds.

Making fodder crops economically more attractive



Association between cereals and legumes is encouraged as legumes improve soil fertility and cereal yields. Fodder legumes species were selected according to their cycle length (perennial species were preferred to avoid re-sowing every year) and vegetative behaviour (creeping but non-twinning species to avoid losses on the cereal crop). Promising results were experienced with *Desmodium uncinatum*.

Development of the livestock industry is a Lao government priority, but will not be possible without intensification of animal fodder systems. This requires protection of fodder resources and fertilisers for the very infertile areas. A key strategy could be to promote new farming systems in which improved fodder resources can provide benefits both for crops and livestock production.



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PO Box 10990, Vientiane, Lao PDR; email: pronaexk@laotel.com, ciradca@laotel.com; Tel/Fax: (856 21) 770027



**Lao National Agro-Ecology Programme – PRONAE
PCADR**

**Development and implementation
of Direct-Seeding Mulch-Based
Cropping Systems in South-East
Asia**

***“Illustrations from the Lao National
Agro-Ecology Programme”***



1- Photo: Lucien Ségué – Cirad

(National road 6 from Phonsavanh to Sala Phoukhouné)

Farming systems throughout Laos have changed drastically over the last 15 years due to a range of factors. In remote areas, the traditional swidden system with long rotations has come under pressure, primarily due to modification of land access and increasing population pressure. Intensification of shifting cultivation, with longer periods of cropping and more frequent returns to a given field, has rendered this system unable to face the main challenges of food safety, soil and water conservation and environmental protection. However, maintaining productive capacity of the soil is a crucial element for long-term improvement of smallholders' conditions and poverty alleviation.



2- Photo: Pierre Grard – Cirad

(Kenthao district, southern Xayabury)

In some areas where market forces are prevalent (e.g. southern Xayabury in the Mekong corridor), traditional farming systems have given way to more conventional high-input agricultural systems based on the production of cash crops such as maize, rice-bean (*Vigna umbellata*), peanuts, Job's tears (*Coix lacryma*), black cowpeas (*Vigna unguiculata*) and sesame. This development, by way of intensification, depends mainly on local market accessibility, transfer of technologies from Thailand and the financial capacities of local enterprises.



3- Photo: Pierre Grard – Cirad

(Plain of Jars, Xieng Khouang province)

In the vicinity of Phonsavanh, it is estimated that more than 60,000ha of acidic infertile savannah grasslands are under-utilised by smallholders. On the higher plains, farming systems are mainly based on lowland rice and extensive livestock production.



4- Photo: Hoà Tran Quoc – Cirad
(Southern Xayabury)

Cropping is largely opportunistic, related to the demands of the Thai market. Land preparation, based on burning residues and ploughing on steep slopes, has allowed for cultivation of large upland areas every year. Due to its low labour requirements and high labour productivity, maize is widely sown and spreads to new areas every year - more than 15,000 ha was sown in southern Xayabury in 2004 - while crop rotation tends to be abandoned.



5- Photo: Hoà Tran Quoc – Cirad
(Southern Xayabury)

Initial assessment of this ‘resource-mining’ agricultural development shows dramatic land erosion, and destruction of roads and paddy fields.



6- Photo: Hoà Tran Quoc – Cirad
(Southern Xayabury)

Land preparation based on burning residues and ploughing on steep slopes has allowed for cultivation of large upland areas.



7- Photo: Hoà Tran Quoc – Cirad
(Southern Xayabury)

Increasing use of pesticides is another major issue from this agricultural intensification. Herbicides are now widely used for land preparation after burning or ploughing, and for post-emergence application on maize.



8- Photo: Hoà Tran Quoc – Cirad
(Southern Xayabury)

Southern Xayabury has experienced significant rural growth. However, even very good soils can be rapidly degraded. Such damage to natural resources and cultivated area has immediate negative social and economic impacts.



9, 10- Photos: Hoà Tran Quoc – Cirad
(Southern Xayabury)

Experimental units representative of local bio-physical and farming system diversity were set up to test a large range of cropping systems and technologies. Soil and crop management, cultivars, others inputs and natural conditions are cross-linked to obtain a set of highly varied conditions. Throughout the trial, comparisons are made between traditional cropping systems, which remain the reference, and different levels of DMC system optimisation.

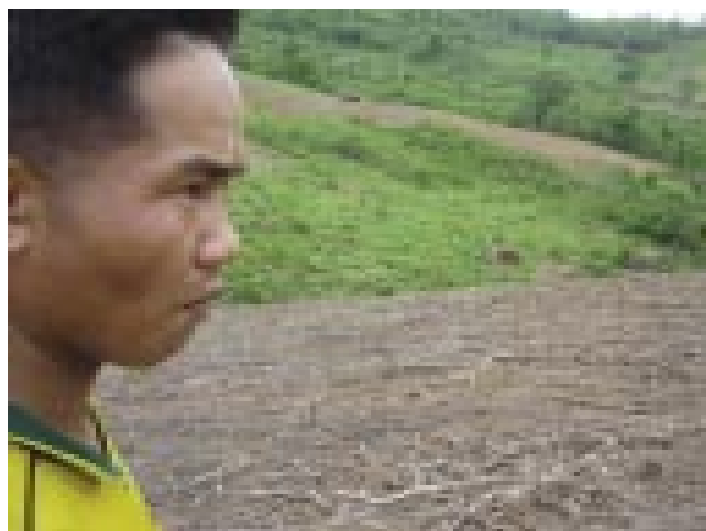


11- Photo: Chanthaly Keoudouangsy – Pronae
(Southern Xayabury)

Farmers groups were organised to validate technical options for decreasing production cost and labour, and for limiting soil erosion. The first DMC systems were implemented on cash crops such as maize, Job's tears and rice-bean.

12- Photo: Hoà Tran Quoc – Cirad
(Southern Xayabury)

On-farm validation of DMC systems based on residue management. Left, maize after ploughing; right, direct seeding of maize on former crop residues.



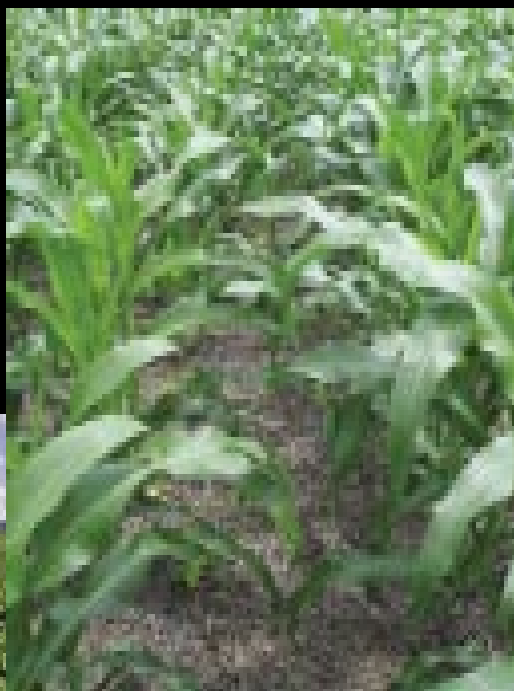
13- Photo: Hoà Tran Quoc – Cirad
(Southern Xayabury)

Direct seeding of maize on rice-bean residues (*Vigna umbellata*).



13, 14, 15- Photos: Hoà Tran Quoc – Cirad
(Southern Xayabury)

Cash crops like Job's tears (*Coix lacryma Jobi*) and rice-bean (*Vigna umbellata*) are key crops for implementing this first level of DMC systems because of: i) their high dry matter production (over 20t.ha⁻¹ for Job's tears); ii) their low residue degradation due to a high lignin content; iii) the low rate of C/N for rice-bean residues; iv) the low level of animal exportation owing to low palatability of both species. Presented here are rotational sequences with Job's tears (*Coix lacryma Jobi*), rice-bean (*Vigna umbellata*) and rice.



16- Photo: Hoà Tran Quoc – Cirad
(Southern Xayabury)

Maize direct seeded on rice-bean residues. Uniform repartition of residues (4 t.ha⁻¹) gives efficient soil protection and weed control.



17- Photo: Pierre Grard – Cirad
(Southern Xayabury)

Rotational sequence of two years between rice-bean and maize.



18- Photo: Hoà Tran Quoc – Cirad
(Southern Xayabury)

Maize direct-seeded on rice-bean residues. Yields recorded under this DMC system, with good soil conditions (Parklay district), reach 8t.ha⁻¹ and show high labour productivity (US\$10).

19, 20- Photos: Hoà Tran Quoc – Cirad

(Southern Xayabury)

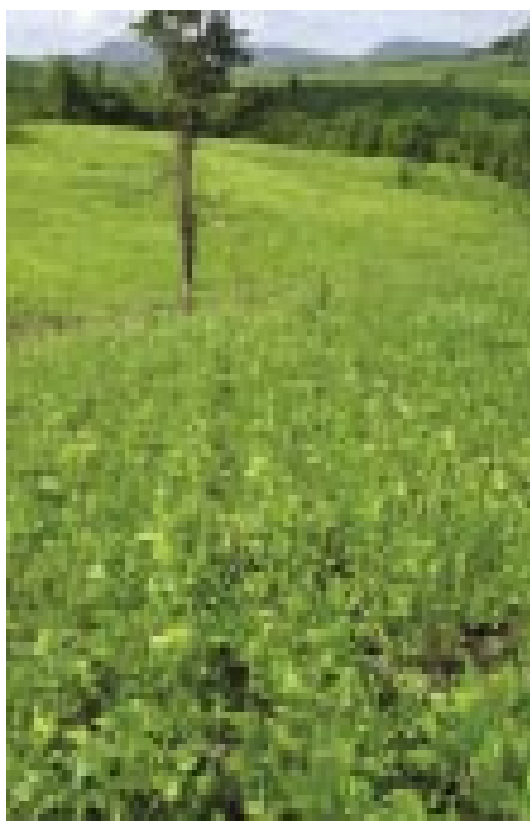
On-farm evaluation of the first step of DMC systems based on former crop residues: left, maize direct-seeded on crop residues (four years) and right, maize after ploughing.



21, 22- Photos: Hoà Tran Quoc – Cirad

(Southern Xayabury)

Uniform repartition of rice-bean residues before sowing (left) and direct seeding of maize (right).



23- Photos: Hoà Tran Quoc – Cirad

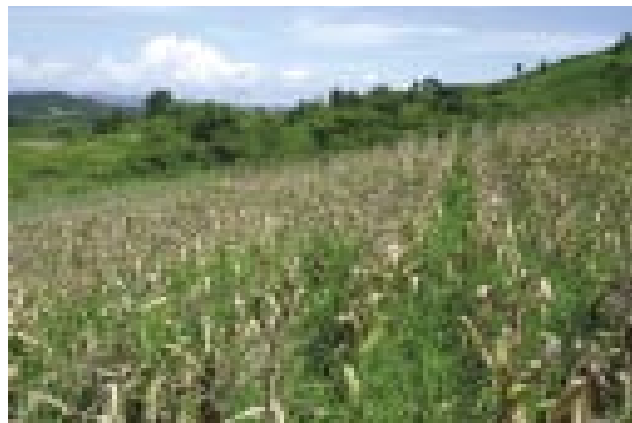
(Southern Xayabury)

DMC systems enhance crop diversification and integration of cropping and livestock production (relay crop can be use as forage). Rice-bean field and *Brachiaria ruziziensis* pasture (background).

24- Photo: Hoà Tran Quoc – Cirad

(Southern Xayabury)

Second step of DMC systems integrates soil and crop management (association, rotation and/or annual crop sequence) in order to diversify production through grain and forages. This will reduce agronomic, economic and climatic risks while optimising the main functions of DMC systems through adequate use of main and relay crops, resulting in: i) permanent soil protection; ii) integrated management of weeds and pests; iii) improvement of soil fertility; iv) enhancement of agro-biodiversity; and v) better integration of crops, livestock production and perennial crops.



25- Photo: Hoà Tran Quoc – Cirad

(Southern Xayabury)

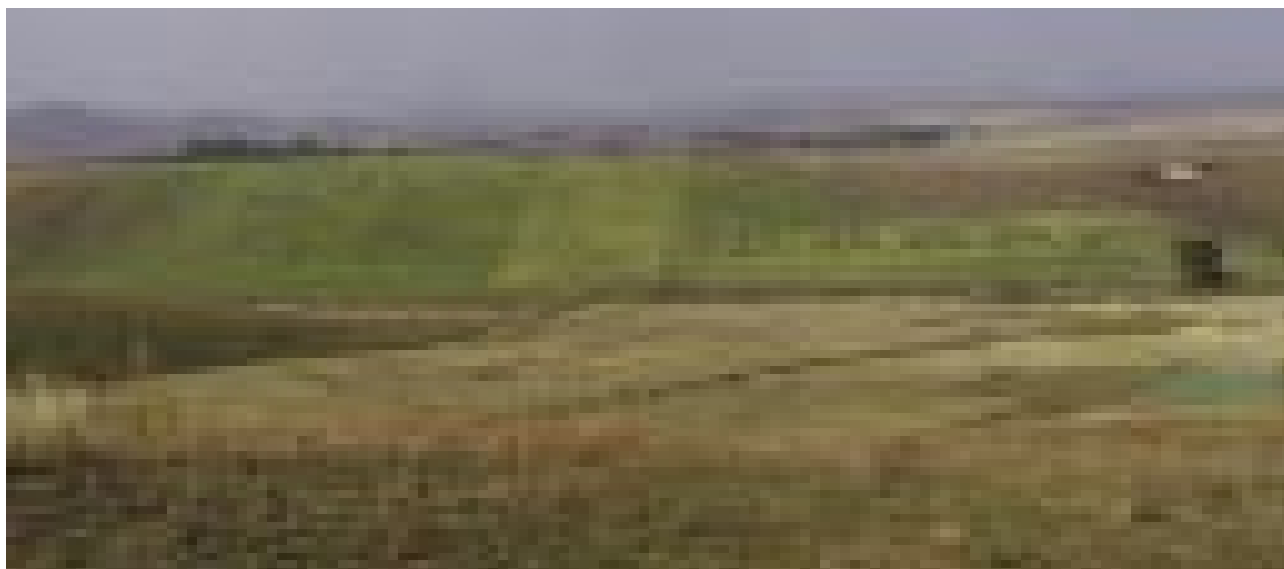
Rotations with direct-seeded grain crops (maize) followed by forage production for grazing. Species like *Brachiaria ruziziensis* are sown at the first weeding stage by seed broadcasting in order to limit labour input. After two or three years, depending on the farmer's strategy, crops can be direct seeded on forage mulch.



26, 27- Photos: Hoà Tran Quoc – Cirad

(Southern Xayabury)

Optimisation of the main functions of DMC systems with use of a cover crop (*Brachiaria ruziziensis*). Direct-seeding of rice-bean on Job's tears residues (left) and *Brachiaria ruziziensis* mulch (right).



24- Photo: Pascal Lienhard – Cirad

(Plain of Jars, Xieng Khouang province)

A large range of forage species, tolerant to drought and soil acidity, is being used to regenerate waste lands in the vicinity of Phonsavanh (provincial capital of Xieng Khouang province). Rotational sequences between improved pasture and edible crops direct-seeded onto forage mulch are tested. Regeneration of savannah grasslands can increase the productivity of this area and reduce degradation of natural resources in other parts of the province.



25- Photo: Pascal Lienhard – Cirad

(Plain of Jars, Xieng Khouang)

Cattle grazing on *Brachiaria ruziziensis* pasture.



26- Photo: Pierre Grard – Cirad

(Plain of Jars)

Direct-seeding of soybean on *Brachiaria ruziziensis* mulch.



27- Photo: Pierre Grard – Cirad

(Plain of Jars)

Direct-seeding of *Stylosanthes guianensis* (forage legume) on natural pasture land.

28, 29- Photos: Pierre Grard – Cirad

(Plain of Jars)

Forage species are used to improve soil fertility by i) replacing mechanical actions through strong root systems; ii) increasing organic skeleton and biological activity; iii) tapping deep ground water and recycling nutrients leached deep in the soil.



30- Photo: Pierre Grard – Cirad

(Plain of Jars, Xieng Khouang province)

Many smallholders have requested technical and financial support to improve natural pasture lands and start DMC systems. Forage seeds collections using bag-nets are carried out to extend forage species during the next season.



31- Photo: Pascal Lienhard – Cirad

(Plain of Jars)

Smallholders are increasingly demanding improved pasture lands.



31, 32, 33, 34- Photos: Thammakham Sosomphou and Pascal Lienhard – Cirad; text from Michellon et al. – Cirad, Tafa

(Plain of Jars)

A traditional African farming technique allows recovery of soil fertility and increased production by slow burning of organic material in trenches, covered with soil. This practice of soil smouldering leads to a rise in pH (up to 1 unit on acid ferrallitic soils), CEC, and available phosphorus, and improved soil structure. Using rice husk and straw gives the highest gain in yield, especially on ferrallitic soils. This practice burns part of the soil organic matter and should be used cautiously, especially when soil organic matter content is low. It has to be accompanied by cropping practices such as DMC systems, which allow a fast recovery of the burned organic matter.



35, 36- Photos: Pascal Lienhard – Cirad

(Plain of Jars, Xieng Khouang province)

Soil smouldering replaces a heavy and costly mineral fertilisation and gives the opportunity to crop on acidic savannah grasslands usually under-utilised by smallholders.

37- Photo: Hoà Tran Quoc – Cirad

(Parklay district, Southern Xayabury)

Evaluation of new species and soybean cultivars in experimental units.



40- Photo: Pascal Lienhard – Cirad

(Plains of Jars, Xieng Khouang province)

The plain of Jars has great potential for winter crops like wheat, oats and beans. First diversification experiments are testing oats after rice harvesting.

38- Photo: Pascal Lienhard – Cirad

(Nonghet district, Xieng Khouang province)

Evaluation of upland rice varieties.



39- Photo: Hoà Tran Quoc – Cirad

(Southern Xayabury)

Collection of edible crops and forage species.